BARTER FOR PRICE DISCRIMINATION? A THEORY AND EVIDENCE FROM RUSSIA*

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Abstract

Unprecedented demonetization of Russia's transition economy has been explained by tight monetary policy, tax evasion and poor financial intermediation. We show that market power may also be important. We build a model of imperfect competition in which firms use barter for price discrimination. The model predicts a positive relationship between concentration of market power and share of barter in sales. The model has multiple equilibria which may explain persistence of barter in Russia but not in other economies. Using a unique dataset on barter transactions in Russia, we show that the firm-level evidence is consistent with the model's predictions.

JEL Codes: D43, L13, P42.

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1 Introduction

Rapid growth of non-monetary transactions has been one of the most striking features of Russia's transition to a market economy. Russian economy is highly demonetized. Barter and vecksels (firms' IOUs) have become major means of payment after the financial stabilization of 1995. According to various sources, barter accounts for 30 to 70 per cent of inter-firm transactions (Aukutzionek (1998), Karpov (1997), Hendley et al. (1998)). Data on vecksels are scarce but some estimates indicate that they account for 10-20 per cent of inter-firm transactions with total volume being as large as 10 per cent GDP (Voitkova (1999)).[1]

Demonetization of this depth is unprecedented in modern economies.[2] The mainstream economic theory of money has explained why barter is crowded out by fiat money in all developed economies. Kiyotaki and Wright (1989), Williamson and Wright (1994), Banerjee and Maskin (1996) build general equilibrium models with asymmetric information and/or random matching to show that introduction of a universal medium of exchange can increase welfare. The literature considers money to be a superior mode of exchange. The growth of barter in Russia is therefore a challenge to modern economics: it is barter that crowds out the monetary exchange.[3]

There is a number of competing theories that suggest solutions to the puzzle. The most common one explains the prevalence of barter by the liquidity squeeze due to tight monetary policy. This view is maintained by most firm managers. The second explanation is often brought up by government

[1] The estimates from different survey vary a lot. Each survey includes several hundred firms and may well be biased (there are about 16 thousand large and medium size industrial firms in Russia). In the data from IET surveys we use in this paper, 40 per cent of sales are paid in kind and 10 per cent are paid in wechsels. The official data come from firms' financial accounts. These data may be even more distorted because of different prices used in monetary and barter transactions. Our calculations using these data for 1996-98 provide an estimate of the average share of money in sales revenues of 49-52% in 1996-98 with the median being as low as 32-37%.

[2] Although barter trade has been growing in OECD economies, it is still negligible. According to IRTA (1998), barter exchanges between North American companies in 1998 are estimated at 13 bln dollars which is at least ten times less in *absolute terms* than in Russian economy (and Russian economy in 1996 was roughly 15 times smaller than the US one).

[3] Banerjee and Maskin (1996) suggest that barter may prevail in equilibrium when inflation is very high. In Russia, however, the growth of barter was observed *after* inflation was brought down.

officials who say that barter is used by the managers to avoid paying taxes in full. Third, outside investors often claim that managers use barter to divert profits, entrench and delay restructuring. Ellingsen (1998) and Marin and Schnitzer (1999) have suggested that barter in Russia may have emerged as a response to contractual imperfections. Ellingsen (1998) builds a model in which liquidity-constrained agents signal their type via payments in kind. Marin and Schnitzer (1999) assume that barter helps to enforce debt contracts since barter can be used as a hostage. Thus, in their model, barter facilitates exchange between liquidity constrained firms in an environment with costly contracting. Gaddy and Ickes (1998a) suggest that barter is a substitute for restructuring. In their model, managers can invest either in 'relational' capital which facilitates barter within existing trading networks or into 'restructuring' which helps their firms produce goods competitive in the new markets. This implies a negative relationship between growth of barter and restructuring. Woodruff (1999) argues that demonetization is a political phenomenon. Russian government lost the battle to regional governments and large firms who have successfully challenged the federal monopoly to issue money.

We believe that analysis of barter in Russia is incomplete without taking into account the role of market structure. Anecdotal evidence suggests that these are the natural monopolies that are most engaged in barter (Gaddy and Ickes (1998b)). In 1996-97, *Gazprom* (the natural gas monopoly) and *Unified Energy Systems* (the electricity monopoly) reported cash receipts of as low as 15-20 per cent total revenue (Pinto et al. (1999)). The rest of their revenues came in vecksels, coal, metal, machinery and even jet fighters. It is also interesting that *all* case studies discussed in Woodruff (1999) refer to firms that are either national or regional natural monopolies.

In this paper, we build a model of barter as a means of price discrimination that predicts a positive relationship between concentration of market power and share of barter in sales. In addition to non-linear pricing, sellers can offer contracts with payments in kind. Since quality of the buyer's output is better known to the buyer than to the seller, the seller can use barter contracts as a screening device. The buyers who produce output of high quality prefer to keep it and pay in cash while the buyers with low quality output keep cash and pay in kind. Even in the presence of the adverse selection, sellers may prefer to use barter. Indeed, if there were no barter, some buyers would buy too little (imperfect competition is inefficient). Barter allows to sell to such customers and may therefore be profitable for the sellers.

Our argument suggests that barter in Russia may be similar to barter in other economies. As shown in Caves (1974) and Caves and Marin (1992), price discrimination is responsible for the wide use of countertrade in trade between OECD and less developed countries.[4] Our model is different from one in Caves (1974) in several respects. First, we build a closed model of an imperfectly competitive industry (rather than a monopoly) and solve for partial equilibria taking into account responses of all sellers and buyers in the market. Second, there is an important distinction between international and domestic barter. In the international trade, it is usually possible to separate markets so that first- or third-degree price discrimination can be used. In domestic sales, there is a single market and only incentive-compatible discrimination is feasible. This is crucial for our analysis: self-selection is responsible for emergence of the 'cash demand externality' which in turn results in multiplicity of equilibria. If firm A sells more for cash, the cash prices go down which the most productive customers among those who used to pay in kind. With these customers leaving the barter economy, the average quality of in-kind payments deteriorates and A's competitors have more incentives to sell for cash. The multiplicity of equilibria may explain why barter is used for price discrimination in Russia but not in other countries.[5]

The main implication of our analysis is that barter can indeed emerge in equilibrium as a means of price discrimination even if there are no liquidity constraints. Our model predicts that barter is more likely to occur in concentrated industries and decreases with competition. Moreover, there is a structural break in the strength of the effect: at certain level of competition the industry jumps from high-barter equilibrium to low-barter equilibrium. These predictions are empirically testable. We use a survey of Russian firms in order to check whether our model is consistent with data.

Recent empirical literature on barter in Russia can be roughly divided into two groups according to the empirical methodology used. The first approach is to ask managers how much they barter and why they barter and try to regress their answers on their perceptions of their firms' characteristics such as indebtedness, competitiveness, access to markets etc. The second

[4] See also Ellingsen and Stole (1996) who suggest that international barter may be a device to commit not to engage in unilateral imports. Magenheim and Murrell (1988) put forward yet another reason to use barter for price discrimination: in a repeated game, barter helps not to reveal the seller's type to future customers.

[5] The nature of multiplicity of equilibria in our model is different from Kranton (1996) and Polterovich (1998) where multiplicity emerges due to the thin market externality.

approach is to match the manager's estimates of share of barter in sales with financial accounts of their firms. So in both approaches, the managers provide information on how much they barter. The difference between the approaches is in the source of information on why they barter. The first approach uses the manager's perceptions while the second one relies on official statistics. The first approach may therefore provide a biased view due to managers' imperfect information on their counterparts and competitors and lack of incentives to reveal sensitive information. The second approach gets rid of this bias but is subject to other limitations. There are no official data that allow to estimate some important variables especially those related to the informal economy.

The first approach is used in Commander and Mumssen (1998) (who use the second approach as well), Carlin et al. (2000), Brana and Maurel (1999), Marin and Schnitzer (1999). Commander and Mummsen (1998) find that barter is related to financial difficulties. Tax evasion and corporate governance problems are not reported by managers as primary causes of barter. Brana and Maurel (1999) use panel data to show that the explanations of barter are different for indebted and non-indebted firms. Potentially viable firms use barter to relax liquidity constraints while highly indebted firms take advantage of barter to avoid restructuring. Carlin et al. (2000) find that barter helps to overcome disorganization which is consistent with Marin and Schnitzer (1999) who use data on barter prices and find support for their model that barter serves as a hostage to restore trust among liquidity-constrained trading parties. The second approach is used in Guriev and Ickes (2000) to test whether share of barter in payments for inputs depends on the firm's cash holdings. Unlike the authors using the first methodology, Guriev and Ickes (2000) find no significant relationship.[6]

In this paper, we apply the second approach. Unlike Carlin et al. (2000) and Caves and Marin (1992), we measure competition directly through concentration ratios rather than via managers' perception of competition.[7] We

[6] This result emphasizes the danger of bias produced by the first approach. Indeed, if firm A says that firm B pays A in kind because B has no money, A may be mislead since A does not have complete information on B's financial standing. Moreover, if B knows that A accepts barter, B will not need money, so that the lack of liquidity may be endogenous. See Guriev and Ickes (2000) for a detailed discussion. It is interesting that when Commander and Mumssen (1998) use the second approach (p. 27), they also find no significant relationship between barter and financial variables (access to credit and overdue payables).

[7] Caves and Marin (1992) asked firms whether they face little or substantial competition

find that barter is indeed correlated with concentration. We also test for a structural break and show that it is indeed present in the data.

The rest of the paper is organized as follows. In Section 2, we build a model of a price-discriminating monopoly that can use barter. The model is then extended to the case of oligopoly. Section 3 contains results of our empirical analysis. Section 4 concludes.

2 The model

In this Section we study a simple model of barter as a screening device for price discrimination. In Subsection 2.1 we start with a standard model of a monopoly that sells to a continuum of buyers. We introduce notation and make technical assumptions. In Subsection 2.2, we add barter. In Subsection 2.3, we extend the analysis for the case of oligopoly and solve for Cournot equilibria.

2.1 The setting

Consider a monopoly seller S that supplies an input to a continuum of buyers B (industrial firms). The marginal cost of production of the input is constant and equal to $c \in [0, 1]$. Each buyer has a linear technology which converts a unit of the input into one unit of output worth v to the buyer. The buyer's maximum capacity is one unit. The input cannot be resold by one buyer to another buyer: once purchased, it can only be used in production.[8] The buyer's outside option is zero so that buyers add value whenever $v > c$ and destroy value if $v < c$.

We assume that v is distributed on $[0; 1]$ with a c.d.f. $F(v)$. The buyer's productivity v is her private information, but the distribution function $F(\cdot)$ is common knowledge.[9]

nationally and worldwide. Also, they asked whether the firms were leaders or followers in the respective markets. Carlin et al. (2000) used the following measures of competition. First, they asked managers how many competitors they had. Second, they asked about price elasticity of demand for the firm's products. Their empirical analysis finds weak positive relationship between concentration and barter.

[8] The best examples of such inputs are natural gas and electricity that can be transported only via the distribution system owned by the seller. Also, if the input is buyer-specific and/or transportation costs are high, every resale is very costly.

[9] If S knew v, perfect (first-degree) price discrimination would be feasible. Russian

The timing is as follows. S offers a menu of contracts, then the buyer learns her type v and chooses which contract to take. The contract is executed and the trade occurs.

Let us make some technical assumptions about the distribution function. Denote $G(v)$ the average value of output given it is below $v:$

$$G(v)=\int_0^v xdF(x)/\int_0^v dF(x) \tag{1}$$

Assumption A1. Density $f(v)=F'(v)$ is continuous and positive. $v-G(v)$ is an increasing function of v. The hazard rate $f(v)/(1-F(v))$ is a non-decreasing function of v.

This assumption is satisfied whenever distribution is sufficiently close to uniform. For the uniform distribution $F(v)=v$, $G(v)=v/2$, $v-G(v)=v/2$, $f(v)/(1-F(v))=1/(1-v)$.

To have a benchmark, let us find the social optimum. The first best is to supply one unit of the input to the buyers with $v\geq c$ and shut down all the others. This outcome would be implemented if the input market were perfectly competitive. The price of the input would then be set equal to its marginal cost c. Only buyers with $v\geq c$ would buy the input and produce. Total social welfare would be $W^*=\int_c^1(v-c)f(v)dv=G(1)-c+(c-G(c))F(c)$.

In the second best, the seller offers a menu of contracts $\{(p,q)\}$: '*buy* $q\in[0,1]$ *units of input and pay* p *in cash'.* If a buyer with quality v picks a contract (p,q) her utility is $vq-p$ while the seller gets $p-cq$. According to the Revelation Principle we can re-formulate the problem as follows: the monopoly offers a menu of contracts $\{(p(v),q(v))\}$, $v\in[0,1]$ such that each type v selects a contract $(p(v),q(v)\}$. The seller maximizes

$$\int_0^1(p(v)-cq(v))f(v)dv$$

subject to incentive compatibility constraints

$$vq(v)-p(v)\geq vq(v')-p(v') \text{ for all } v,v'\in[0,1]$$

economy, and especially its part involved in barter transactions, is very non-transparent (Pinto et al. (1999)), so that assuming asymmetric information seems to be rather adequate. Also, uncertain economic environment reduces the value of learning in repeated interaction.

and individual rationality constraints $vq(v) - p(v) \geq 0$ for all $v \in [0, 1]$.

A straightforward analysis of this adverse selection problem (see Salanie (1997)) gives

$$q(v) = \arg \max_{q \in [0,1]} q \left[v - c - \frac{1 - F(v)}{f(v)} \right]$$

The seller offers only two contracts $\{(p^m, 1), (0, 0)\}$.[10] The price p^m solves

$$p^m - c = (1 - F(p^m))/f(p^m). \tag{2}$$

All buyers with $v \geq p^m$ will buy and produce and the others will not.[11] The deadweight loss

$$\int_c^{p^m} (v - c)f(v)dv = (G(p^m) - c)F(p^m) + (c - G(c))F(c) \tag{3}$$

arises due to the fact that buyers with $v \in (c, p^m)$ that could potentially add value, do not produce. This equilibrium is essentially a textbook case of a non-discriminating monopoly serving a market with the demand curve $D(p) = 1 - F(p)$.

2.2 Barter as a means of price discrimination

Now we shall introduce in-kind payments. Suppose that the seller can offer the buyers a menu of triples $\{(p, b, q)\}$: buy $q \in [0, 1]$ units of input for cash payment p and in-kind payment $b \leq q$. The buyer produces q units of output out of which b units are given back to the seller.

In this paper, we introduce all possible shortcomings of barter in order to show that in the presence of market power barter can emerge even if it is very inefficient.[12] The first drawback of barter is the need for double coincidence of wants. We assume that the seller values the buyer's output less than the buyer herself. A unit of buyer v's product is worth only αv to S, where $0 < \alpha < 1$. This assumption implies that the seller has an inferior technology

[10] The intuition for the corner solution is simple: both B and S are risk-neutral and their valuations of the input are linear in quantity. In the equilibrium, there are no contracts with $q \in (0, 1)$.

[11] We assume that, whenever indifferent, the buyers choose to buy the input and produce.

[12] Also, we neglect liquidity constraints that may make money inferior to barter.

for re-selling or using the buyer's product.[13] The cost of barter $1-\alpha$ may be interpreted as a probability that there is no double coincidence of wants so that S has to throw the in-kind payments away.

The other problem is that, unlike money, the barter is not perfectly divisible.[14] For the simplicity's sake we assume the extreme degree of indivisibility and will only allow contracts with $b = \{0, 1\}$. Together with the condition $b \leq q$, indivisibility implies that S can offer only barter contracts with $b = q = 1$.

If the buyer v chooses a contract (p, b, q), she gets $v(q-b)-p$. The seller gets $\alpha vb - cq + p$. Again, according to the Revelation Principle, the seller chooses $p(v)$, $q(v) \in [0,1]$ and $b(v) \in \{0,1\}$, $b(v) \leq q(v)$ that maximize

$$\int_0^1 (p(v) + \alpha v b(v) - cq(v)) f(v) dv \tag{4}$$

subject to incentive-compatibility constraints

$$v(q(v) - b(v)) - p(v) \geq v(q(v') - b(v')) - p(v') \text{ for all } v, v' \in [0,1] \tag{5}$$

and individual rationality constraints

$$v(q(v) - b(v)) \geq 0 \text{ for all } v \in [0,1]. \tag{6}$$

In order to characterize the solution, we shall introduce more notation. Denote p^{mb} the solution to

$$p^{mb}(1-\alpha) = (1 - F(p^{mb}))/f(p^{mb}). \tag{7}$$

Proposition 1 *The optimal menu of contracts $\{(p, b, q)\}$ is as follows. There exists $\bar{c}$ such that if $c < \bar{c}$, S chooses to use barter and offers the following*

[13] A more general approach would be to assume that the value of buyer v's output to the seller is an arbitrary function $\beta(v)$ where $\beta(v) \leq v$. We have checked some alternative formulations and found that analysis becomes much more complex without adding more insights.

[14] The indivisibility assumption is a shortcut for taking into account increasing returns in barter exchange. The legal, storage and transportation costs per unit of barter decrease with the amount bartered. Therefore exchanging small portions of the good may be prohibitively costly.

menu of contracts: $\{(p^{mb}, 0, 1), (0, 1, 1), (0, 0, 0)\}$.[15] *If* $c > \bar{c}$, *S chooses not to use barter and offers the couple* $\{(p^m, 0, 1), (0, 0, 0)\}$ *where* p^m *solves (*2).

The intuition is again simple. Since both seller's and buyers' preferences are linear in quantity, there are no contracts with q between zero and one.

Further on, we will only study the case where the monopoly is better-off using barter.

Assumption A2. The monopoly is better-off using barter: $c < \bar{c}$.

When S chooses to use barter, the buyers with higher valuations $v \geq p^{mb}$ buy and pay in cash while the buyers with lower valuations buy and pay in kind. The barter customers with $v < c$ that should be closed down in the social optimum are pooled together with the efficient ones $v \in [c, p^{mb}]$ and there is no possibility to sort them out (barter is indivisible).[16] On the other hand if the cash price is sufficiently high, serving this pool of barter customers is still profitable for the seller. The average quality of the output is $G(p^{mb})$ and therefore S gets profit whenever $p^{mb} > p^*$, where

$$\alpha G(p^*) = c. \tag{8}$$

A2 implies $p^{mb} > p^*$. Indeed, we have the following chain of inequalities: $(p^{mb} - c)(1 - F(p^{mb})) + (\alpha G(p^{mb}) - c)F(p^{mb}) > (p^m - c)(1 - F(p^m)) = \max_p \{(p - c)(1 - F(p))\} \geq (p^{mb} - c)(1 - F(p^{mb}))$. Therefore $(\alpha G(p^{mb}) - c)F(p^{mb}) > 0$. The other implication of A2 is that the monetary price is higher in the presence of barter: $p^{mb} > p^m$ (see the Proof). The intuition is simple: if there were no barter, increasing the cash price would result in losing customers, while in the presence of barter, these customers are not lost

[15] This menu is similar to a standard debt contract with a privately known value of collateral. The contract states: "*S supplies a unit of input to B; B must pay S* p^{mb} *in cash or S gets ownership of B's output*". The barter trade is therefore similar to (inefficient) liquidation. Unlike the conventional models of debt (Hart (1995)), we assume that there is no possibility for ex post renegotiation (or that the renegotiation is very costly). The model with renegotiation where the buyer has at least some bargaining power has a very similar equilibrium, except, of course, elimination of the deadweight loss due to the double coincidence of wants.

[16] In equilibrium, the barter customers get zero rent (S has full bargaining power). We assume that, whenever indifferent between producing and closing down, the buyers choose to produce. If the opposite were the case, S would have to offer the menu of contracts $\{(p^{mb} - \epsilon, 0, 1), (-\epsilon, 1, 1), (0, 0, 0)\}$ where $\epsilon > 0$ is a very small amount. Then the barter customers would get the rent of ϵ.

— they switch to paying in kind and actually improve the average quality of the in-kind payments.

Example. Consider a uniform distribution $f(p) \equiv 1$. In this case $\bar{c} = (1-\alpha/2)^{-1/2} - 1$, $p^{mb} = (2-\alpha)^{-1}$, $p^m = (1+c)/2$, $p^* = 2c/\alpha$.

The welfare effect of barter is ambiguous. The deadweight loss in the equilibrium with barter is $(1-\alpha)G(p^{mb})F(p^{mb})+ (c - G(c))F(c)$ which may be greater or less than the deadweight loss would be if the barter contracts were not allowed (3). There are two sources of inefficiency. First, the direct inefficiency of barter is due to the fact that the seller gets the good that she does not need as much as the buyer $\alpha < 1$. Second, the inefficient buyers with $v < c$ get the input and produce. These two effects may be either larger or smaller than the deadweight loss (3) without barter that is caused by underprovision of the input by the monopoly seller.

This simple model illustrates the relevant policy trade-offs. If barter were prohibited, a monopoly would produce too little, some efficient buyers would close down. However, if barter is allowed, the losses are not only due to the lack of double coincidence of wants (proportional to $1-\alpha$). There are also losses due to the asymmetric information about the quality of payments in kind. The average value of the barter payments is greater than the input cost but some of the barter customers actually subtract value. Thus the model rather supports the claim that barter helps inefficient firms survive and delay restructuring since they are pooled together with profitable ones in the barter market.[17] This is an implication of indivisibility of barter. If barter payments were perfectly divisible, the seller would be able to discriminate against the inefficient buyers and only sell for barter to the buyers with $v > c/\alpha$ (see the Comment in the Proof of Proposition 1 in the Appendix).

2.3 Barter in oligopoly

In this Subsection we extend our analysis to the case of oligopoly. Suppose that there are N identical sellers with the same marginal cost c. We will look at the second-degree price discrimination under Cournot oligopoly assuming

[17] Our model is an adverse selection model and is not very appropriate for analyzing restructuring. One should consider a moral hazard model with investment in productivity v. Apparently, barter would provide less incentives for such investment. Indeed, the buyer gets rent $U(v) = \max\{v - p^{mb}, 0\}$. If barter were not allowed, $U(v) = \max\{v - p^b, 0\}$. A2 implies that $p^{mb} > p^b$, hence less incentives to invest in productivity.

that sellers determine how much to sell for cash and for barter taking into account self-selection of buyers.

Our model is an extension of the Model I in Oren et al. (1983). Each firm offers the following menu of contracts: a non-linear cash tariff $(p(q), 0, q)$, $q \in [0,1]$ ("*pick any* $q \in [0,1]$ *and pay* $p(q)$ *in cash*") and a barter contract $(\overline{p}, 1, 1)$ ("*take one unit of input and pay one unit of output and* $\overline{p}$ *in cash*"). Each firm chooses the optimal tariff $p(q), \overline{p}$ in order to maximize their profits given the market shares of their competitors (in equilibrium, all tariffs will be the same). Each buyer selects the contract that maximizes her rent $U(v) = v(q-b) - p$. Buyers compare three options: (a) the outside option that gives a trivial payoff, (b) the barter contract that gives $\overline{U} = -\overline{p}$ and (c) the cash contract that gives $U(v) = \max_{q\in[0,1]} vq - p(q)$. The incentive compatibility and individual rationality constraints imply (see Lemma 2 in the Appendix) that there exists such $\overline{v}$ that: (i) all buyers with $v < \overline{v}$ take the outside option or pay in kind and (ii) all buyers with $v > \overline{v}$ pay in cash; (iii) among the cash customers, higher types buy greater quantities. Let us denote $v^*(q)$ the highest type that buys q units of input and pays in cash. Apparently, $v^*(q)$ is an increasing function.

We define the Cournot equilibrium as in Oren et al. (1983).[18] Each seller i is characterized by a function $T_i(q)$ — the number of customers buying no more than q units for cash from i. Apparently, $\sum_{i=1}^{N} T_i(q) = F(v^*(q))$ for all $q > 0$. $T_i(0)$ is the number of customers buying for barter from i. Each seller takes $T_j(q)$, $j \neq i$ as given and chooses the tariffs $p(q)$, $\overline{p}$ and $T_i(0)$ to maximize profit

$$\begin{aligned}(\alpha G(v^*(0)) - c)(F(v^*(0)) - T_{-i}(q))T_i(0)1(\overline{p} \geq 0) + \\ + \int_0^1 (p(q) - cq)d(F(v^*(q)) - T_{-i}(q)) \end{aligned} \qquad (9)$$

subject to the constraint that $v^*(q)$ is the inverse of the buyer's optimal response to $p(q)$, $\overline{p}$. Here $T_{-i}(q) = \sum_{j\neq i} T_j(q)$, $1(\overline{p} \geq 0)$ is the indicator function that equals 1 whenever $\overline{p} \geq 0$ and 0 otherwise. We will look for symmetric equilibria where $T_i(q) = T_j(q)$ for all i, j, q.

[18] There are several approaches to modelling second-degree price discrimination under oligopoly. Ivaldi and Martimort (1994) and Stole (1995) look at the second-degree price discrimination under duopoly with imperfect substitutes. Those models are too complicated to study comparative statics with regard to change in the number of sellers. This is why we turn to the Cournot oligopoly with perfect substitutes studied in Oren et al. (1983).

Lemma 1 *In any Cournot equilibrium, there are no buyers who buy* $q \in (0,1)$ *for cash.*

As well as in the monopoly case, the linear utility and cost functions rule out the intermediate quantities. This makes the contract menu very simple: some buyers choose to buy one unit for cash, some buy one unit for barter and the rest do not buy at all. The function $T_i(q)$ is now fully characterized by two numbers: $T_i(0)$ and $T_i(1)$. Each firm sells $y_i = T_i(1) - T_i(0)$ for cash at the market price $P = p(1) - p(0)$ and $z_i = T_i(0)$ for the buyers' output. In the Cournot equilibrium, total quantity supplied to the cash market $Y = \sum_{i=1}^{N} y_i$ equals quantity demanded $\int_P^1 f(v)dv = 1 - F(P)$. The rest of buyers $v < P$ are indifferent between buying in the barter market or not buying at all. The average quality of the barter payment is therefore $E(v|v < P) = G(P)$. Since buyers in the barter market are indifferent between buying and not buying we assume that whenever the total supply in the barter market $Z = \sum_{i=1}^{N} z_i$ is below $F(P)$, the demand is stochastically rationed so that the average quality of payments in kind remains $G(P)$.

The seller i takes other seller's strategies y_j and z_j as given and maximizes

$$\pi(y_i, y_{-i}, z_i) = P(y_i + y_{-i})y_i + z_i \alpha G(P(y_i + y_{-i})) - cy_i - cz_i \tag{10}$$

subject to

$$0 \leq z_i \leq F(P(y_i + y_{-i})) - z_{-i}. \tag{11}$$

Here $y_{-i} = \sum_{j \neq i} y_j$, $z_{-i} = \sum_{j \neq i} z_j$. The inverse demand function $P(Y)$ is given by $Y = 1 - F(P)$ so that $P'(Y) = -1/f(P(Y))$.

Formally, we shall look for the Nash equilibria in the game among N sellers whose strategies are couples (y_i, z_i) that satisfy (11) and $y_i \geq 0$. The payoffs are given by (10).[19]

We will classify equilibria by the presence of barter and then study comparative statics with regard to change in N.[20] Notice that firm i has an incentive to sell for barter whenever $\partial \pi / \partial z_i = \alpha G(P(Y)) - c \geq 0$ or $P(Y) \geq p^*$.

[19] Strictly speaking, the game is not defined in the normal form, since other players' strategies influence both payoff function and the set of possible strategies for each player. However, we can easily reformulate the problem by setting the payoff equal to (10) if (11) is satisfied and $-\infty$ otherwise.

[20] In this stylized model we take N to be a positive real number. However, at $N = 1$ the equilibria will indeed coincide with the ones in case of monopoly.

1. *'Barter' equilibria.* This is the case where $P(Y) \geq p^*$. The objective function (10) increases with z_i. Therefore the sellers want to barter as much as possible $z_i = F(P) - z_{-i}$. The first order condition for y_i implies $y_i = f(P)\left[P - \alpha G(P) - \alpha(P - G(P))(F(P) - z_{-i})/F(P)\right]$.[21] Adding up for $i = 1, .., N$ and dividing by $f(P)$ we obtain the equation for equilibrium price:

$$(P - \alpha G(P))N - \alpha(P - G(P)) = \frac{1 - F(P)}{f(P)}. \tag{12}$$

   We will denote $p^b(N)$ the price P that solves (12) for a given N. The necessary and sufficient condition for existence of a barter equilibrium is $p^b(N) \geq p^*$. The total amount of barter sales is $Z = F(p^b(N))$. The barter sales of individual sellers z_i must satisfy $\sum_{i=1}^N z_i = Z$. In the symmetric equilibrium $z_i = F(p^b)/N$ and $Y_i = (1 - F(p^b))/N$. There is also a continuum of asymmetric equilibria. In all equilibria, however, P and Z are the same.

2. *'No-barter' equilibria.* If $P \leq p^*$, the sellers do not barter $z_i = 0$ and the first order condition for y_i implies $y_i = (P - c)f(P)$. Adding up and dividing by $f(P)$ we get the conventional Cournot equilibrium:

$$(P - c)N = \frac{1 - F(P)}{f(P)} \tag{13}$$

   Let us introduce $p^{nb}(N)$ as a solution to (13). The necessary and sufficient condition for existence of a no-barter equilibrium is $p^{nb}(N) \leq p^*$. The total amount of barter sales is zero.

3. *'Rationed barter' equilibria.* If $P = p^*$, the sellers are indifferent about how much to offer for barter. The first order condition for y_i implies $y_i = (p^* - c)f(p^*) - z_i(p^* - G(p^*))f(p^*)/F(p^*)$. Adding up, we get

$$Z/F(p^*) = \left[(p^* - c)N - (1 - F(p^*))/f(p^*)\right] / \left[\alpha(p^* - G(p^*))\right] \tag{14}$$

   Barter sales of individual sellers z_i must satisfy $\sum_{i=1}^N z_i = Z$. The necessary and sufficient condition for the existence of a rationed-barter equilibrium is (11) i.e. $0 \leq Z/F(p^*) \leq 1$. These inequalities hold if

[21] We have used the identity $G'(p) = (p - G(p))f(p)/F(p)$.

and only if both inequalities $p^b(N) \geq p^*$ and $p^{nb}(N) \leq p^*$ hold. Thus the rationed barter equilibrium exists if and only if both 'barter' and 'no-barter' equilibria exist.

Let us denote N^b a solution to $p^b(N) = p^*$ and N^{nb} a solution to $p^{nb}(N) = p^*$.

Example. For the uniform distribution $f(p) \equiv 1$, $N^{nb} = (1-2c/\alpha)/(2c/\alpha - c)$, $N^b = (1 - 2c/\alpha + c)/(2c/\alpha - c)$.

Proposition 2 *Assume A1-A2. Both N^b and N^{nb} exist and $N^b > N^{nb}$. The set of equilibria of the game above is as follows:*

1. *If $N < N^{nb}$ then there is a unique stable equilibrium which is a barter equilibrium*

2. *If $N > N^b$ then there is a unique stable equilibrium which is a no-barter equilibrium*

3. *If $N \in (N^{nb}, N^b)$ then there are three equilibria two of which (barter and no-barter) are stable and one (rationed barter) is unstable.*

4. *If $N = N^b$ then there are two equilibria: a stable one (no-barter) and an unstable one (barter).*

5. *If $N = N^{nb}$ then there are two equilibria: a stable one (barter) and an unstable one (no-barter).*

Figure 1 illustrates the structure of equilibria according to Proposition 2.

The intuition for multiplicity of equilibria at $N \in (N^{nb}, N^b)$ is as follows. Whenever one seller chooses to sell more for cash, she drives down the cash price of the input. The additional cash purchases are made by the buyers who were initially the most efficient ones among those buying for barter. With these buyers switching from barter to cash, the average quality of payments in kind goes down. The other sellers will therefore have incentives to sell more for cash and less for barter.[22]

It it interesting to see how the share of barter in sales in the industry $B = Z/(Z + Y)$ changes with the number of sellers N. In the barter

[22] This externality is somewhat similar to aggregate demand externality in the new Keynesian macroeconomics or the market size externality in the development economics (Ray (1998)).

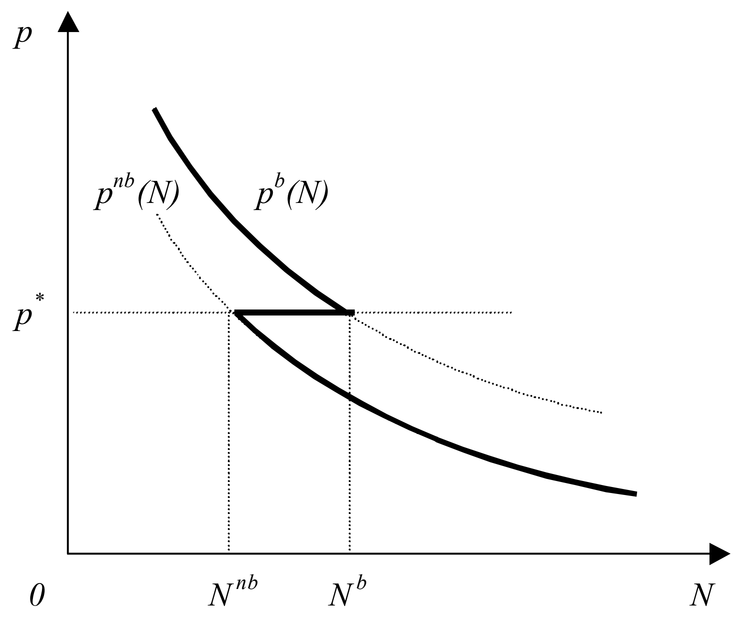

Figure 1: Oligopoly price P as function of number of sellers N.

equilibria $B = Z = F(p^b(N))$. Since $p^b(N)$ is a continuous decreasing function, B is a continuous decreasing function of N. In the no-barter equilibria $B = Z = 0$. In the rationed barter equilibria $Y = 1 - F(p^*)$, Z is a linear function of N given by (14). Therefore $B = [1 + (1 - F(p^*))/Z]^{-1}$ is a continuous increasing hyperbolic function of N that connects points $(N^{nb}, 0)$ and $(N^b, F(p^*))$ in the (N, B) space (see Figure 2).

Let us briefly discuss what properties of the model determine the structure of equilibria. First, both in barter and no-barter equilibria, prices go down if number of sellers increases. Second, for a given market structure, the cash price in barter equilibrium is greater than the price in no-barter equilibrium. This is also intuitive. In barter equilibria, sellers have more incentives to charge higher prices because the marginal buyers who would leave the market in case of no-barter equilibria, now simply switch to barter and therefore contribute to profits from barter sales. Third, in barter equilibria

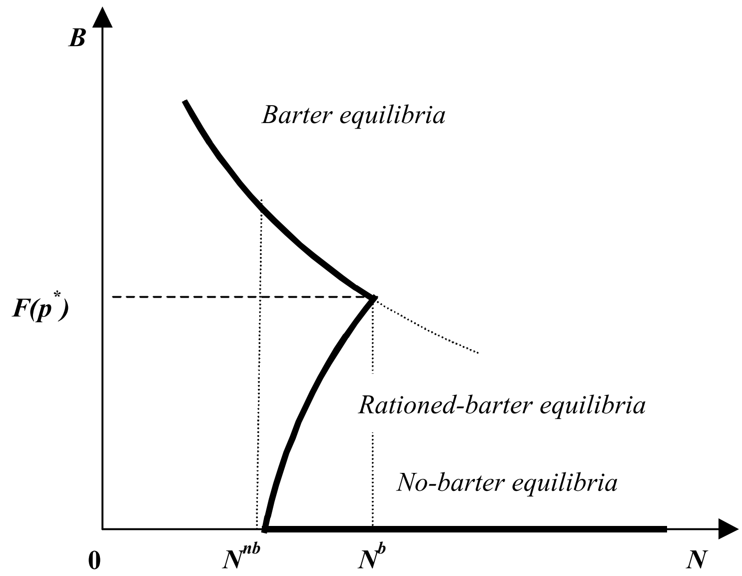

Figure 2: Share of barter sales in total sales $B = Z/(Z+Y)$ as a function of number of sellers N.

the cash price should be above certain level p^* otherwise the average quality of payments in kind is below marginal cost and barter is not profitable. Similarly, in no-barter equilibria price should be below p^*. Under these three conditions, the structure of equilibria should be exactly like in Figures 1 and 2.

It is not clear whether the barter equilibrium is more or less efficient than the no-barter one. In the no-barter equilibria, there is a deadweight loss since the cash price is higher than the marginal cost. Therefore some efficient buyers do not produce. In the barter equilibria, all buyers produce including the value-subtracting ones. Also, there are transactions costs of barter $(1-\alpha)F(p^b(N))G(p^b(N))$. The social planner has to compare the deadweight loss in the no-barter equilibrium where too many firms are shut down but transaction costs are low with one in the barter equilibrium where

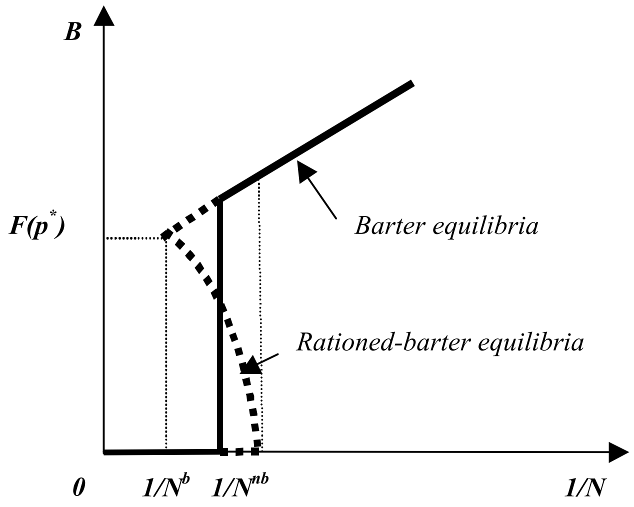

Figure 3: Share of barter in sales B as a function of concentration $1/N$. At certain concentration below $1/N^{nb}$ there occurs an abrupt jump from barter to no-barter equilibrium. At concentrations above $1/N^{nb}$, the industry is in the barter equilibrium.

too few firms are shut down and transaction costs are high.

3 Empirical analysis

3.1 Empirical predictions

The model implies the following empirical predictions. First, the greater the market concentration $1/N$, the greater the level of barter in sales $B = R/(R+Q)$. Second, there should be a structural break in the range $1/N \in [1/N^b, 1/N^{nb}]$ where the industry jumps from the no-barter equilibrium to the barter equilibrium. This is illustrated in the Fig.3 (which is essentially Fig.2 redrawn in $(1/N, B)$ coordinates).

When testing these empirical implications, we will have to control for two alternative explanations of a positive relationship between market concentration and barter. First, market concentration is correlated with firm's size. At the same time, double coincidence of wants is a smaller problem for larger firms so they should have more barter. (In terms of our model, larger firms tend to have higher α.)

The other argument is that in consumer good industries there are many small firms, and all firms receive cash from individual consumers (or retail trade companies). Indeed, for individual consumers, the transactions costs of barter are prohibitively high. In the intermediate good industries, the minimum efficiency scale is high, there are fewer firms and they supply to other firms (or wholesale trade) who are able to pay in kind. Thus, if we assume that the farther from the retail market the less cash is paid, there should be a positive correlation between distance from the consumer market and barter. Since there is also a positive correlation between the distance to market and concentration, barter and concentration should be correlated.

3.2 Data and variables

We use the dataset 'Barter in Russian industrial firms' built in the New Economic School's Research Project 'Non-Monetary Transactions in Russian Economy'. This dataset was created by matching the annual surveys of managers of Russian industrial firms conducted since 1996 by Serguei Tsoukhlo (Institute of Economies in Transition, Moscow) with Goskomstat database of Russian firms (Federal Committee for Statistics of Russian Federation) and RECEP Import Penetration Database (Russian European Center for Economic Policy). Since the penetration ratios were only available for years for 1996, we ran regressions for a cross-section of 1996.[23]

The barter data include about six hundred firms. The barter data are answers of firms' managers to the following (eight) questions: '*how much of your firm's inputs (outputs) were paid in rubles, in dollars, in kind and in wechsels?*' The Goskomstat database includes compulsory statistical reports that all large and medium-size firms must submit to the Federal Statistics Committee. There are over 16 thousand firms in the database. After matching barter data with the Goskomstat data we ended up with 475 observations. The sample includes firms of all sizes with annual sales from tens of thousands US dollars to several hundred million US dollars (about 4% of the sample

[23] In a working paper Guriev and Kvassov (2000), we also included 1997 data (without import penetration) and the results were similar. The RECEP Foreign Trade Project was completed in 1997, and we are not aware of any source of industy-level import penetration data for later years.

have sales exceeding \$100 million US dollars). Neither *Gazprom* nor *Unified Energy Systems* are included in our sample.

Import database contains import penetration ratios for all product categories and all industries, so we can adjust market concentration for import penetration.

The concentration ratios CR4 (share of four biggest firms in total sales of an industry) were calculated for 5-digit OKONKh industries using the Goskomstat database and then adjusted for import penetration using RECEP database.[24] Russian 5-digit industries are similar to US 4-digit industries; there are about 450 five-digit industries in Russia. In our sample, only 149 industries are represented so that we have on average 3.2 firms in each industry, with up to 22 firms in some industries (the median industry has 7 firms). Given the average CR4 in these industries is almost 40 per cent, this is quite a few. An alternative approach would be to use CR4s for broader (e.g. 4-digit) industries. However, we believe that such concentration ratios are less informative. In Russia's OKONKh classification many 4-digit industries include 5-digit industries that use each other's outputs as inputs in their production. In such 4-digit industries, firm do not compete with each other: their products are not substitutes.

The main goal of empirical analysis is to estimate the effect of concentration on share of barter in sales controlling for other variables that may affect barter. First, we should control for the firm's size. As a proxy for size we use logarithm of annual sales in denominated rubles. (We have also tried other measures of size such as employment and got similar results.)

Second, since our model applies to inter-firm transactions we need to control for sales to foreign and retail customers. The former is easy to measure: we use share of exports in sales $export$.[25] It is less clear how to control for retail sales. As a proxy for sales to consumers we have used a consumer good industry dummy (CGI). We have set $CGI = 1$ for consumer good industries and $CGI = 0$ otherwise. In our sample, 27% firms are in consumer good industries. Unfortunately, CGI is a very crude estimate of a firm's exposure to

[24] We thank David Brown and Annette Brown for providing us with the concentration ratios they have calculated. The CR4s they have obtained coincide with ones that Federal Antimonopoly Committee has included in its Annual Report.

[25] Certainly, it makes sense to distinguish exports by countries. We have tried to include CIS and non-CIS exports separately into regression and found no significant difference. It is no wonder since non-CIS exports include exports to developing countries where countertrade is common.

consumer market and is in fact industry-specific rather than firm-specific.[26] In what follows, we report the estimates where CGI dummy was simply added to the regressions; we have also tried to run separate regressions for industries with $CGI = 1$ and $CGI = 0$ and obtained similar results.

In order to control for transportation costs, we have introduced the following regional dummies: $rgmsk = 1$ if the firm is based in Moscow, $rgural = 1$ if the firm is based in Urals, $rgsib = 1$ if the firm is based in Siberia or Far East. The base category is European Russia except Moscow. To control for technological differences between the industries, we also include ten broad industry dummies in the regressions (these roughly correspond to 2-digit industry codes, see the definitions in the Table A1 in the Appendix). In our model, all industries are the same except for the market concentration. In reality, however, there may be some industry-specific characteristics that facilitate or hinder barter exchanges (e.g. per unit transportation costs).

As a measure of market concentration we use concentration ratios $CR4$ and import-adjusted concentration ratios $CR4ia$. $CR4$ is the share of four largest firms in total output of all firms calculated for a 5-digit industry, and $CR4ia = CR4 * (1 - imp)$. Here imp is the import penetration ratio for a 5-digit industry (we assume that the world market is competitive).

The summary statistics and the correlation matrix are shown in the Appendix A. The share of barter in sales varies a lot across firms. It is distributed almost uniformly between 0 and 0.83. Only 10% of the sample have no barter at all which means that we are unlikely to have industries with $N < N^{nb}$ in our sample.

The signs of pair-wise correlations are mostly intuitive. There is indeed more barter in concentrated industries (controlling and not-controlling for imports), in larger firms and in those which sell less to foreign customers and consumers. Consumer good industries are less concentrated.[27] The need for adjustment of concentration ratios for imports is quite clear: on average, import penetration is 38%, it varies a lot across industries, and

[26] The latest data we have for production of consumer goods at the firm level date back to 1993. In 1993, share of consumers goods in output were indeed correlated with CGI. In consumer good industries $CGI = 1$, the share of consumer goods was 48 per cent while in the other industries it was only 13 per cent. We tried to include the 1993 consumer sales into the regression, and those turned out to be insignificant.

[27] Average $CR4$ for consumer good industries is 24 per cent which is significantly lower than in the other industries (42 per cent). A similar difference is observed for $CR4ia$: 14 vs. 25 per cent. Both differences are significant at 1% level.

import penetration and $CR4$ are positively correlated.

3.3 Empirical results

The results of the basic OLS regressions for share of barter in sales are shown in Table 1. The estimates with imported-adjusted concentration are presented in the columns I-III, while columns IV-VI contain results of regressions with concentration ratios not adjusted for imports. The first regression (I) shows that barter positively and significantly depends on concentration. When we include CGI (column II), the effect of concentration decreases by about a quarter. This may reflect the technological differences between the industries: when we include the 2-digit industry dummies (column III), the coefficient at CGI becomes insignificant while the coefficient at $CR4ia$ even increases. The estimates with $CR4$ instead of $CR4ia$ (columns IV-VI) show that the effect of concentration is weaker and even not significant at 10% level if we do not control for imports. The effects of CGI and 2-digit industry dummies are perfectly similar.

Other coefficients have predicted signs. There is indeed more barter in larger firms. The magnitude of the effect is moderate: the coefficient of 0.014 — 0.022 implies that if one firm is ten times as large as the other one, it will have 3-5 per cent more barter in sales. The effect of exports is similar: the coefficient is negative but not very large (only 18-19 per cent). If a firm's exports increase by one dollar, it will have roughly twenty cents less sold for barter.[28] There is 15 per cent less barter in Moscow, 13 per cent more barter in Urals and 11 per cent more barter in Siberia, than in European Russia, so that geography is an important determinant of barter. Firms in consumer good industries have 8 per cent less barter, and most of this difference comes from the differentials between 2-digit industries.[29]

In order to test for the structural break in $CR4ia$ we have introduced

[28] Commander and Mummsen (1998) obtain a similar estimate for the effect of exports on barter (19 per cent). The fact that the coefficient is below 1, raises a very interesting question. It suggests that many firms are paid for their exports in kind by the intermediaries who then sell the output for hard currency. In our sample, export revenues exceed hard currency receipts for most firms. Therefore the effect of share of exports in sales on barter may also be attibuted to the effect of competition: most Russian firms are price-takers in the foreign markets.

[29] For the sake of brevity, we do not present the coefficients at industry dummies. The food industry has 8% less barter, while pulp and forestry has 13% more barter than other industries. The other differentials are less striking.

B	I	II	III	IV	V	VI
$CR4ia$	0.17** (0.08)	0.13* (0.07)	0.15* (0.08)			
$CR4$				0.10 (0.07)	0.07 (0.06)	0.10 (0.06)
$size$	0.015* (0.008)	0.014* (0.008)	0.022*** (0.008)	0.017** (0.008)	0.016* (0.008)	0.022*** (0.008)
$export$	-0.08 (0.06)	-0.11** (0.06)	-0.18*** (0.06)	-0.09 (0.06)	-0.12** (0.06)	-0.19*** (0.06)
CGI		-0.08*** (0.04)	-0.02 (0.03)		-0.08*** (0.04)	-0.02 (0.03)
$rgmsk$	-0.16*** (0.03)	-0.15*** (0.04)	-0.13*** (0.03)	-0.16*** (0.03)	-0.15*** (0.03)	-0.14*** (0.03)
$rgural$	0.13*** (0.05)	0.14*** (0.05)	0.13*** (0.04)	0.12** (0.05)	0.14*** (0.05)	0.12*** (0.05)
$rgsib$	0.08** (0.03)	0.08** (0.03)	0.11*** (0.03)	0.08** (0.03)	0.09** (0.03)	0.11*** (0.03)
$ind's$	—	—	***	—	—	***
$const$	0.08 (0.13)	0.13 (0.14)	-0.21 (0.13)	0.06 (0.13)	0.11 (0.13)	-0.22* (0.12)
N	475	475	475	475	475	475
R^2	0.13	0.15	0.22	0.13	0.15	0.22

Table 1: OLS regressions for B. Standard errors (in parentheses) are estimated via Huber/White procedure taking into account unobserved correlations within 5-digit industries. Notation: *** significant at 1% level, ** 5% level, * 10% level.

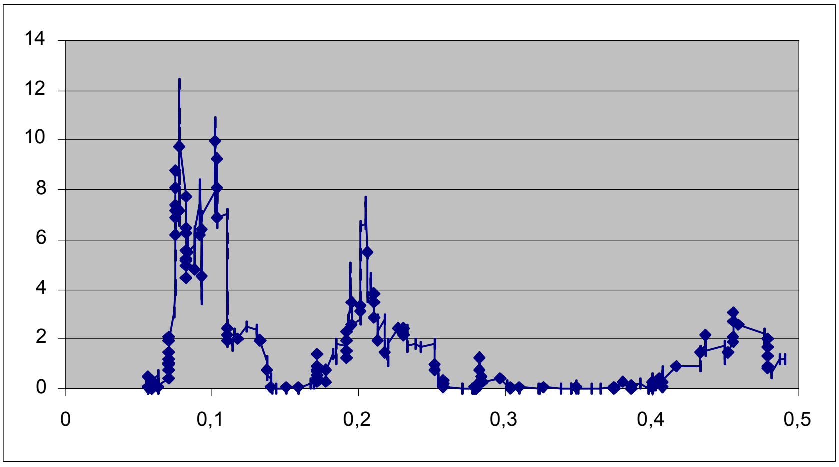

Figure 4: Andrews' statistic as a function of the suspected structural change point ξ in the coefficient β for the equation $B_i = \alpha + \beta * CR4ia_i + \gamma * size_i + \delta * export_i + \zeta * CGI_i + \kappa * rgmsk_i + \lambda * rgural_i + \mu * rgsib_i + \varepsilon$. The two highest peaks are $\xi = 0.078$ and $\xi = 0.103$.

a dummy D_ξ that takes the value of 1 if $CR4ia < \xi$ and $D = 0$ otherwise. Then we added a term $D_\xi * CR4ia$ to our regression. The coefficient at $CR4ia$ would then show the effect of concentration for industries with $CR4ia > \xi$. The effect of concentration for competitive industries $CR4ia < \xi$ would be equal to the sum of coefficients at $CR4ia$ and $D_\xi * CR4ia$.

To find the break point ξ we have calculated the Andrews' statistic (Andrews, 1993) for every $\xi \in [0.05, 0.50]$, i.e. for the whole range $CR4ia$ except for lower and upper deciles (Andrews suggests to cut off upper and lower fifteen per cent of distribution). As shown in the Figure 4, the statistic exceeds the asymptotic critical values calculated in Andrews (1993) at $\xi = 0.078$ and $\xi = 0.103$. In our sample, 28% observations are in the industries with $CR4ia < 0.078$, and 40% are in the industries with $CR4ia < 0.103$.

The results of the regressions with structural change are presented in the Table 2. The results are consistent with our model. Columns I and II contain estimates for the structural breaks at $\xi = 0.078$ and $\xi = 0.103$. As can be seen in Column I, the effect of concentration in more competitive industries ($CR4ia < 0.078$) is much greater (0.20+1.36=1.56) than in more

B	I	II	III	IV
$CR4ia$	0.20*** (0.07)	0.23*** (0.08)	0.22** (0.09)	
$D_\xi * CR4ia$	1.36** (0.59)	1.09*** (0.41)	1.25*** (0.43)	
$CR4$				0.18*** (0.06)
$D_\xi * CR4$				1.23*** (0.30)
$size$	0.015* (0.008)	0.016* (0.008)	0.022*** (0.008)	0.017** (0.008)
$export$	-0.12** (0.06)	-0.12** (0.05)	-0.18*** (0.05)	-0.13** (0.06)
CGI	-0.09** (0.04)	-0.09** (0.03)	-0.04* (0.02)	-0.09** (0.04)
$rgmsk$	-0.14*** (0.03)	-0.15*** (0.03)	-0.13*** (0.03)	-0.14*** (0.03)
$rgural$	0.14*** (0.05)	0.14*** (0.05)	0.13*** (0.04)	0.13** (0.05)
$rgsib$	0.08** (0.03)	0.08** (0.03)	0.10** (0.03)	0.08** (0.03)
$ind's$	—	—	***	—
$const$	0.08 (0.13)	0.06 (0.13)	-0.21* (0.13)	0.03 (0.13)
N	475	475	475	475
R^2	0.17	0.17	0.24	0.17

Table 2: OLS regressions with structural change. Column I shows estimates for $\xi = 0.078$, Column II shows estimates for $\xi = 0.103$. Column III presents estimates for $\xi = 0.082$, which is the optimal structural change point for a regression with 2-digit industry dummies. Column IV show estimates for a regression with concentration ratios not adjusted for imports (the break point in the $CR4$ is $\xi' = 0.162$). Standard errors (in parentheses) are estimated via Huber/White procedure taking into account unobserved correlations within 5-digit industries. Notation: *** significant at 1% level, ** 5% level, * 10% level.

concentrated ones (0.20). The latter coefficient (0.20) can be interpreted as the slope of the barter equilibria curve, while the former (1.56) represents the abrupt jump from no-barter equilibria curve to the barter equilibria curve.

Same results are observed for $\xi = 0.103$: the coefficient for competitive industries is 1.09+0.23=1.32 while the one for concentrated industries is 0.22. To test for robustness, we also perform tests for regressions with 2-digit industry dummies (Column III) and with concentration ratios not adjusted for imports (Column IV). The results are again similar. When the industry dummies are introduced, the structural break point becomes $\xi = 0.082$, and the coefficients become 1.25+0.22=1.47 and 0.22, respectively. In the regressions with CR4s not adjusted for imports, the structural break becomes $\xi' = 0.162$,[30] and the coefficients are 1.23+0.18=1.41 and 0.18.

Thus, the empirical evidence from the cross-section data seems to be consistent with the predictions of the model even controlling for alternative explanations. Certainly, panel data evidence would be more convincing. Indeed, there may be some unobservable firm characteristics that influence their willingness to barter (e.g. managers' "relational capital" (Gaddy and Ickes (1998a)). To make a strong empirical argument, one would have to prove that even controlling for the firm's fixed or random effects, change in competition leads to change in barter. Unfortunately, there are no data to perform this test. Even ideally, there are only two (at most three) observations for each firm: 1996 and 1997.[31] In the years of 1995 and 1998, only during half of a year Russia had low inflation and stable exchange rate.

4 Conclusions and policy implications

We have built a simple model of barter as a means of price discrimination. In our model, buyers are not liquidity constrained and are able to pay cash for their inputs. Also, there is no double coincidence of wants so that the barter transactions are less efficient than the monetary ones. The buyers do need the sellers' product but the sellers do not need the buyers'. The value

[30] The cutoff point $CR4 = 0.162$ is similar to $CR4ia = 0.078$: in our sample, 27% firms are in industries with $CR4 < 0.162$.

[31] We have run 'panel' data estimates for 1996 and 1997 (without controlling for import penetration) and the results were consistent with the model. The results were hardly convincing though, only half of the firms in our sample are present both in 1996 and 1997. Also, the evolution of market concentration over time is quite slow.

of the buyer's output to the seller is only $\alpha < 1$ of its value to the buyer. Second, we assume that barter is indivisible. In the asymmetric information framework this assumption leads to inefficient pooling in the barter market. Since the quality of payments in kind is not observable, inefficient buyers will be engaged in barter along with the efficient ones.

Our main result is that even in the presence of all these deficiencies, barter can emerge in equilibrium if the markets are sufficiently concentrated. The amount of barter increases with concentration. The intuition is straightforward. Since equilibria under imperfect competition are usually characterized by underproduction relative to the social optimum, sellers may be interested in an additional channel of sales even if this channel is costly.

To make the model tractable, we have deliberately introduced a number of simplifying assumptions. We have assumed linear technology, risk neutrality, exogenous probability of double coincidence of wants, perfect substitution of oligopolists' output, extreme indivisibility, allocated all bargaining power to the seller etc. If these assumptions were lifted, the model would become much more complex. For example, assuming convex technology would result in price discrimination both with and without barter. Barter would still represent an additional dimension for price discrimination and would hence be used but the equilibrium contracts would be very complicated.

In order to test predictions of the model, we have built a unique dataset. We matched a survey of managers' on the degree of barter in their firms with the firm-level data from official statistics. The empirical analysis of cross-section data supports our model. Barter positively and significantly depends on the concentration especially in a model with a structural break that our theory predicts.

Our result raises a legitimate question. If barter is explained by high concentration of market power, why is it observed in Russia and is virtually non-existent in other economies? One answer to this question would be that in Russia markets are much more concentrated than in other economies. This claim is well-accepted by general public and policymakers but is not supported by data (see Brown et al. (1994)). Our model may offer another explanation. For the same level of concentration there may be two stable equilibria: one with barter and one without barter. Therefore, path-dependence may be the case. In 1995, a liquidity shock has thrown the economy into a high barter state. Since that time, price flexibility should have restored equilibrium level of real money stock. The real money balances, however, are now 2 to 3 times as low as they used to be. In terms of

Polterovich (1998), Russian economy is in the institutional trap of barter.

The multiple equilibria argument is rather common in modern literature on transition and development. It is basically the essence of so-called 'post-Washington consensus' that is gradually replacing the Washington consensus on economic transition. The post-Washington consensus states that institutions matter a great deal for economic transition and may fail to emerge spontaneously. Government should intervene to promote good institutions, otherwise the economy will find itself in a low-level equilibrium. However, our model does not only confirm that Russia is in a low-level equilibrium. We have also shown that at some level of competition the barter equilibrium disappears and industry jumps to the no-barter equilibrium. This argument has non-trivial policy implications. In order to reduce barter, government should promote competition. Moreover, even if competition policy may have had a little effect on barter so far, the government should not give up. Our model (along with empirical analysis) suggests that barter may fall dramatically when a certain threshold level of competition is achieved.

The other question is whether policymakers should fight barter. Our model provides no clear ranking of the equilibria in terms of social welfare. We show that from the social planner's point of view the trade-off is as follows. Under imperfect competition, the equilibrium without barter is characterized by underproduction: many efficient firms close down. The barter equilibrium is too soft: all efficient firms produce but so do the inefficient ones. Also, the barter equilibrium is characterized by high transaction costs. The model predicts that policymakers who are more concerned with excess employment would rather choose the barter equilibrium as one with fewer closures and mass redundancies. This may explain why local politicians encourage barter relatively more often than the federal government. Certainly, our model is not a general equilibrium one; it does not take into account some important negative consequences of demonetization. Widespread barter reduces transparency in the economy which in turns leads to poor corporate governance, lower tax collection and greater corruption.

Appendix A: Tables

Table A1. Description of the variables and summary statistics. Variables $CR4$, imp, $CR4ia$, CGI are defined for 5-digit OKONKh industries. Variables $ind1 - ind11$ are 2-digit industry dummies.

Variable	Explanation	Mean	S.D.	Median	Min	Max
B	Share of barter in sales	0.37	0.24	0.36	0	0.83
$CR4$	4-firm concentration	0.37	0.26	0.33	0.04	1
imp	Import penetration	0.36	0.26	0.33	0.003	1
$CR4ia$	Import-adjusted CR4	0.22	0.19	0.15	0	0.99
$size$	Log sales	17.0	1.7	16.9	11.1	22.3
$export$	Share of export in sales	0.08	0.17	0.01	0	0.97
CGI	Consumer good industry	0.27	-	-	0	1
$rgmsk$	Moscow	0.13	-	-	0	1
$rgural$	Urals	0.05	-	-	0	1
$rgsib$	Siberia and Far East	0.09	-	-	0	1
$ind1$	Electricity	0	-	-	0	1
$ind2$	Fuel	0.01	-	-	0	1
$ind3$	Ferrous metals	0.08	-	-	0	1
$ind4$	Non-ferrous metals	0.03	-	-	0	1
$ind5$	Chemical	0.12	-	-	0	1
$ind6$	Machinery	0.25	-	-	0	1
$ind7$	Pulp and forestry	0.08	-	-	0	1
$ind8$	Construction materials	0.11	-	-	0	1
$ind9$	Textile	0.15	-	-	0	1
$ind10$	Food	0.15	-	-	0	1
$ind11$	Other	0.03	-	-	0	1

Table A2. The correlation matrix. *** denotes significance at 1% level, * denotes significance at 10% level.

	B	$CR4$	imp	$CR4ia$	$size$	$export$	cgi
B	1						
$CR4$	0.16***	1					
imp	-0.04	0.25***	1				
$CR4ia$	0.18***	0.79***	-0.28***	1			
$size$	0.17***	0.28***	-0.07	0.29***	1		
$export$	0.02	0.23***	0.08*	0.16***	0.32***	1	
CGI	-0.19***	-0.29***	-0.13***	-0.13***	-0.15***	-0.19***	1

Appendix B: Proofs

PROOF OF PROPOSITION 1.

According to Lemma 2, the incentive compatibility and participation constraints (5)-(6) imply the following properties of self-selection. There exists such $\overline{v}$ that: (i) all buyers with $v < \overline{v}$ take the outside option or pay in kind; (ii) all buyers with $v > \overline{v}$ pay in cash; (iii) among the cash customers, higher types buy greater quantities: $q(v)$ is a non-decreasing function of v for all $v > \overline{v}$.

Let us calculate the buyer's rent. Consider arbitrary $v', v'' : v' < v''$. Using the incentive compatibility constraints (19) we obtain

$$q(v') - b(v') \leq \frac{U(v'') - U(v')}{v'' - v'} \leq q(v'') - b(v''). \tag{15}$$

Since $q(v) - b(v)$ is monotonic (Lemma 2), we can integrate (15):

$$U(v) = U(0) + \int_0^v [q(x) - b(x)]\, dx = U(\overline{v}) + \int_{\overline{v}}^v q(x)dx \tag{16}$$

for $v > \overline{v}$.

The case with $\overline{p} > 0$ is equivalent to the model without barter solved in Subsection 2.1: the optimal menu is $\{(p^m, 0, 1), (0, 0, 0)\}$. Let us concentrate on the case where the seller offers a barter contract with $\overline{p} \leq 0$. Then all the buyers with $v < \overline{v}$ take this contract and $U(\overline{v}) = \overline{U} = -\overline{p}$.

Substituting $p(v) = v(q(v) - b(v)) - U(v)$ into (4), we rewrite the S's problem as follows. The seller chooses $\overline{U} \geq 0$, $q(v) \in [0, 1]$ and $b(v) \in \{0, 1\}$ to maximize

$$-\overline{U} + \int_0^{\overline{v}} [\alpha v - c]\, f(v)dv + \int_{\overline{v}}^1 \left(v - c - \frac{1 - F(v)}{f(v)} \right) q(v)f(v)dv. \tag{17}$$

Apparently, S sets $\overline{U}$ equal to zero (or a very small amount to make it strictly more attractive than the outside option) and

$$q(v) = \arg\max_{q \in [0,1]} \left(v - c - \frac{1 - F(v)}{f(v)} \right) q$$

for all $v > \overline{v}$ where $\overline{v}$ is to maximize

$$\Pi(\overline{v}) = (\alpha G(\overline{v}) - c)F(\overline{v}) + (\max\{\overline{v}, p^m\} - c)(1 - F(\max\{\overline{v}, p^m\})) \qquad (18)$$

Let us calculate $d\Pi/d\overline{v}$. If $\overline{v} < p^m$ then $d\Pi/d\overline{v} > 0$ whenever $\overline{v} > c/\alpha$. If $\overline{v} < p^m$ then $d\Pi/d\overline{v} > 0$ whenever $\overline{v} < p^{mb}$. Thus the solution depends on the relationship among c/α, p^m and p^{mb}. Assumption A1 implies that p^m is always between c/α and p^{mb}. It is either $c/\alpha \leq p^m \leq p^{mb}$ or $c/\alpha \geq p^m \geq p^{mb}$. Indeed, $p^m > p^{mb}$ is equivalent to $(1 - F(p^m))/f(p^m) < (1 - F(p^{mb}))/f(p^{mb})$ and therefore $p^m - c < p^{mb}(1-\alpha) < p^m(1-\alpha)$ which implies $p^m < c/\alpha$. Similar argument proves that $p^m < p^{mb}$ implies $p^m > c/\alpha$. Therefore the maximizer of (18) is either $\overline{v} = 0$ or $\overline{v} = p^{mb}$ with the latter possible only if $c/\alpha < p^m < p^{mb}$ is the case. Since $\overline{v} = 0$ is a solution without barter we are interested in $\overline{v} = p^{mb}$. In this case the seller gets the payoff $p^{mb}(1-F(p^{mb}))+\alpha G(p^{mb})F(p^{mb})-c$.

Hence the optimal menu of contracts is either $\{(p^{mb}, 0, 1), (0, 1, 1), (0, 0, 0)\}$ or $\{(p^m, 0, 1), (0, 0, 0)\}$ whichever provides the seller with a higher payoff. Let us denote $\bar{c}$ the value of c that solves

$$\max_{p\in[0,1]} [p(1 - F(p)) + \alpha G(p)F(p)] - c = \max_{p\in[0,1]} [(p - c)(1 - F(p))] .$$

The seller chooses to use barter whenever the left-hand side is greater than the right-hand side, i.e. $c < \bar{c}$. Apparently, $\bar{c}$ increases with α : $d\bar{c}/d\alpha = G(p^{mb})F(p^{mb})/F(p^m) > 0$; $\bar{c} \to 0$ at $\alpha \to 0$.

Comment. If barter were perfectly divisible $b(v) \in [0, 1]$, the solution would be very different. There could be two cases. If $p^{mb} < p^m$ then $b = 0$ and $q = 1$ whenever $v > p^m$. If $p^{mb} > p^m$ then $q = 1$ whenever $v > c/\alpha$ and $b = 1$ for $v < p^{mb}$ (S can sort the barter customers). The former case coincides with the monopoly equilibrium without barter. In the latter case, buyers are split into three groups. The most efficient buyers pay cash price p^{mb}, the buyers with intermediate productivity $v \in (c/\alpha, p^{mb})$ pay in kind and the least productive buyers do not produce. Notice that in this equilibrium both all buyers with $v \leq p^{mb}$ receive zero rent and are indifferent between producing and paying in kind or not producing at all. Above, we assumed that whenever indifferent, buyers choose to produce. Therefore, to make buyers with $v < c/\alpha$ shut down and buyers with $v > c/\alpha$ produce, the seller must offer some infinitesimal reward to the latter. This can be done through making $1 - b(v)$ being strictly positive although very small. Although in equilibrium $b(v)$ is either 0 or very close to 1, perfect divisibility of barter is crucial for separating buyers with $v \in (0, c/\alpha)$ and $v \in (c/\alpha, p^{mb})$. ■

Lemma 2 *If a menu of contracts* $\{(p(v), b(v), q(v))\}$, $q(v) \in [0,1]$, $b(v) \in \{0,1\}$, $b(v) \leq q(v)$ *satisfies the incentive compatibility and participation constraints (5)-(6) then the following is the case. There exists such* $\overline{v}$ *that: (i) all buyers with* $v < \overline{v}$ *take the outside option or pay in kind and (ii) all buyers with* $v > \overline{v}$ *pay in cash; (iii) among cash customers, higher types buy greater quantities.*

PROOF. S may offer a menu of cash contracts $(p, q, 0)$ and one barter contract $(\overline{p}, 1, 1)$. The buyer's rent in equilibrium is $U(v) = v(q(v) - b(v)) - p(v)$. Buyers who choose the barter contract get $\overline{U} = -\overline{p}$. They will prefer it to the outside option if and only if $-\overline{p} \geq 0$. It is important that if the barter contract is better than the outside option for any buyer, it is also so for every buyer. Thus if the barter contract is offered and $-\overline{p} \geq 0$, all buyers buy, produce and pay either in kind or in cash.

Let us prove that there is adverse selection: the barter customers are the ones with lower v's. The amount of output kept by the buyer $q(v) - b(v)$ is a monotonic function of v. Indeed, let us take arbitrary v',$v'' \in [0,1]$ such that $v' < v''$ and write down incentive compatibility constraints:

$$\begin{aligned} v''(q(v'') - b(v'')) - p(v'') &\geq v''(q(v') - b(v')) - p(v'), \\ v'(q(v') - b(v')) - p(v') &\geq v'(q(v'') - b(v'')) - p(v''). \end{aligned} \tag{19}$$

Adding up these inequalities, we get $(v'' - v')\{q(v'') - b(v'')) - (q(v') - b(v'))\} \geq 0$. Therefore $v' < v''$ implies $q(v'') - b(v'') \geq q(v') - b(v')$. Thus, if any buyers pay in kind, those are the buyers with lower quality v than those who pay in cash. Indeed, for barter customers $q(v) - b(v) = 0$, while for the cash customers $q(v) - b(v) = q(v) \geq 0$. Hence, there exists $\overline{v}$ such that buyers with $v < \overline{v}$ pay in kind and buyers with $v > \overline{v}$ pay in cash.

If $-\overline{p} < 0$, there are no buyers who choose the barter contract. If some buyers take the outside option, those are the buyers with lower quality v than those who pay in cash. Indeed, for the customers who drop out, $q(v) - b(v) = 0$ which is again less than $q(v) - b(v) = q(v)$ for the cash customers.

Among those who pay in cash, buyers with higher v buy and produce more: since $b(v) = 0$, $q(v)$ weakly increases with v. ■

PROOF OF LEMMA 1. The seller maximizes (9) by choosing three scalar numbers $T_i(0), \overline{p}, p(0)$ and a function $p'(q)$, $q \in [0,1]$. In this proof we will concentrate on the latter and will show that the optimal choice of $p'(q)$ does not allow for intermediate purchases for cash $q \in (0,1)$. Integrating the second term in (9) by parts, we get

$$p(0)(1-T_{-i}(\overline{q})-F(v^*(0))+T_{-i}(0))+\int_0^{\overline{q}}(p'(q)-c)(1-T_{-i}(\overline{q})-F(v^*(q))+T_{-i}(q))dq$$

where $\overline{q}$ is the quantity chosen by the buyers of the highest type $v = 1$.

The first term in (9) does not depend on $p'(q)$, $q \in (0,1)$. Therefore, the seller chooses $p'(q)$ to maximize

$$\int_0^{\overline{q}}(p'(q)-c)(1-T_{-i}(\overline{q})-F(v^*(q))+T_{-i}(q))dq. \tag{20}$$

Buyers choose q solving $\max_{q\in[0,1]} vq - p(q)$. Assume that there exist buyers that buy $q \in (0,1)$ for cash. Then the first-order condition must hold $v = p'(q)$. Substituting $v^*(q) = p'(q)$ into (20) we find

$p'(q) = \xi^*(q) = \arg\max_\xi(\xi-c)(1-T_{-i}(\overline{q})-F(\xi)+T_{-i}(q))$. The first-order condition is $(\xi^*-c)f(\xi^*) = 1-T_{-i}(\overline{q})-F(\xi^*)+T_{-i}(q)$. Using the symmetry condition $T_i(q) = T_j(q) = \frac{1}{N-1}T_{-i}(q) = \frac{1}{N}F(v^*(q))$ we obtain

$$\xi^* - c = \frac{1-F(\xi^*)}{Nf(\xi^*)}.$$

Assumption A1 implies that such ξ^* exists and is unique. It is important that ξ^* is the same for all q. Since $p'(q) = \xi^*$ does not depend on q, the price is linear: $p(q) = p(0) + \xi^* q$. Therefore all buyers with $v < \xi^*$ will choose not to buy $q = 0$ and all buyers with $v > \xi^*$ will buy one unit $q = 1$. The set of buyers who are indifferent $v = \xi^*$ has a zero measure. ■

Proof of Proposition 2. We will organize the proof in several steps.

Step 1. Prove that $p^b(N)$ and $p^{nb}(N)$ are decreasing functions of N and $p^b(N) > p^{nb}(N)$ for all $N < N^b$.

Solving (12) for N we obtain

$$N = 1 + [(1-F(P))/f(P) - (1-\alpha)P] \,/\, [P - \alpha G(P)] \tag{21}$$

which is a decreasing function of P. Consequently, the inverse function $p^b(N)$ is also decreasing. Since $p^b(1) = p^{mb} > p^*$ and $p^b(\infty) = 0$, there exists a unique solution to $p^b(N) = p^*$. Similarly, (13) implies $N = (1 - F(P))/\,[(P-c)f(P)]$ which is a decreasing function. Since $p^{nb}(0) = 1 > p^*$ and $p^b(\infty) = c < p^*$ there exists a unique solution to $p^{nb}(N) = p^*$.

For all $N < N^b$, we have $p^b(N) > p^*$ and therefore $\alpha G(p^{nb}(N)) > c$. Using (12) and (13) for every N holds

$$\frac{1}{N} = \frac{(p^{nb} - c)f(p^{nb})}{1 - F(p^{nb})} = \frac{(p^b - c)f(p^b)}{1 - F(p^b)} - \frac{f(p^b)[(\alpha G(p^b) - c) + \frac{\alpha}{N}(p^b - G(p^b))]}{1 - F(p^b)}$$

which implies $p^{nb}(N) > p^b(N)$.

Step 2. Prove that $N^b > N^{nb}$.

This follows from Step 1. Indeed, both $p^{nb}(N)$ and $p^b(N)$ are continuous decreasing functions, $p^{nb}(N) < p^b(N)$ for all $N < N^b$ and $p^{nb}(N^{nb}) = p^b(N^b) = p^*$.

Step 3. Existence of equilibria.

The barter equilibrium exists if and only if $p^b(N^b) \geq p^*$ i.e. $N \leq N^b$. The no-barter equilibrium exists if and only if $p^{nb}(N^{nb}) \leq p^*$ i.e. $N \geq N^{nb}$. The rationed barter equilibrium exists if and only if both barter and no-barter equilibria exist.

Step 4. Stability of equilibria.

Barter equilibrium at $N < N^b$ and no-barter equilibrium at $N > N^{nb}$ are stable. Indeed if there is no barter and one seller deviates by offering a positive amount of barter sales, other sellers have no incentives to deviate. If, in a barter equilibrium, one seller deviates by offering less barter then other sellers's best response is to capture the unattended customers and therefore restore total barter sales equal to $F(P)$.

The rationed barter equilibrium is unstable. Indeed, if one seller chooses to sell a little more for barter and a little less for cash, the price in the cash market will increase which would make average quality of payments in kind $\alpha G(P)$ greater than marginal cost of production c. Then all other sellers will want to sell for barter and the barter equilibrium will be reached. Similarly, if one seller decides to deviate from rationed barter equilibrium selling more for cash and less for barter, $\alpha G(P)$ will fall below c and everyone will give up selling for barter so that the no-barter equilibrium will be reached. ■

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