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ABSTRACT

Barter For Price Discrimination?*

Unprecedented growth of barter is a striking phenomenon of Russia's transition. The explanations of barter include tight monetary policy, tax evasion and poor financial inter-mediation. We show that the 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 the concentration of market power and the share of barter in sales. We also show that barter disappears at a certain level of competition. The model has multiple stable equilibria which may explain persistence of barter. Using a unique data set on barter transactions in Russia, we show that empirical evidence is consistent with the model's predictions.

JEL Classification: D43, L13, P42
Keywords: barter, price discrimination, oligopoly

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NON-TECHNICAL SUMMARY

Rapid growth of non-monetary transactions is one of the most striking features of Russia's transition to a market economy. Russian economy has become highly de-monetarized. According to various sources, barter accounts for 30–70% of inter-firm transactions. Russia's de-monetarization experience is therefore a challenge to the modern economic theory of money that has explained why barter is crowded out by fiat money in all developed economies.

There are a number of competing explanations of barter in Russia. Most managers maintain the view that barter is explained by the liquidity squeeze due to tight monetary policy. The second reason is often brought up by government officials who say that barter is used by managers to avoid paying taxes in full. Third, outside investors often claim that managers use barter to divert profits, entrench and delay restructuring. In this Paper, we argue that discussion of barter in Russia is incomplete without taking into account the role of market structure. Indeed, the anecdotal evidence suggests that these are the natural monopolies that are most engaged in barter.

We build a 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 of the buyer's output to the seller is only a fraction of its value to the buyer. Second, we assume that barter is indivisible. In the asymmetric information framework these assumptions lead 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 with 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.

In order to test predictions of the model, we have built a unique data set. We matched a survey of managers on the degree of barter in their firms with the firm-level data from the official statistics. The empirical analysis 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 more concentrated than in other economies. This claim is well accepted by the general public and policy-makers but is not supported by data. 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 there may be a path-dependence. In 1995, a liquidity shock has thrown the economy into a high barter state. Since that time, price flexibility should have restored the equilibrium level of real money balances. The real money supply, however, is now 2 to 3 times as low as it used to be which supports the multiple equilibria hypothesis.

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. The government should intervene to promote good institutions, otherwise the economy will find itself in a low-level equilibrium. However, what our model suggests is not simply a restatement that Russia may be in a low-level equilibrium. We have shown that at some level of competition the barter equilibrium disappears and industry jumps to the no-barter equilibrium. This argument does have non-trivial policy implications. In order to reduce barter, the government should promote competition. Moreover, even if competition policy may have had 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.

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 has become highly demonetized. Since the macroeconomic stabilization of 1995, the broad money base M2 has been only about 15 per cent of annual GDP (see the official statistics in Russian Economic Trends (1995-99)). The three primary non-monetary means of payment have been barter, inter-enterprise arrears (or offsets) and wechsels (bills of exchange). Inter-enterprise arrears emerged during high-inflation in 1992-94. Since stabilization in 1995 they went down but did not entirely disappear. Barter and wechsels have become major means of payment after the stabilization in 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 wechsels 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. 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. Russia's demonetization experience is therefore a challenge to modern economics: it is the barter that crowds out the monetary exchange.

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

[1] There are no official data on barter and wechsels. The estimates come from enterprise surveys. Each survey includes several hundred firms and may well be biased (there are about 16 thousand large and medium size firms in Russian industry). This is why the estimates differ so much. 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.

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 (1999) suggest that barter is a natural substitute for restructuring. In their model, managers can invest their time either in 're-lational' 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.

We believe that discussion 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 *RAO UES* (the electricity monopoly) have reported cash receipts low as 15-20 per cent of total revenue (Pinto et al. (1999)). The rest of the revenue came in wechsels, coal, metal, machinery and even jet fighters.

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 prices, monopoly 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, monopoly 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 monopoly.

The argument that barter can be used for price discrimination is certainly not new. Caves and Marin (1992) analyze countertrade deals between OECD and less developed countries. They show that price discrimination may be responsible for the wide use of countertrade transactions in the world economy.[2] Our model is different from Caves and Marin's in several respects.

[2]See also Ellingsen and Stole (1996) who suggest that international barter may be a

First, we build a closed model of an imperfectly competitive industry 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. In domestic sales, there is a single market and only incentive-compatible discrimination is feasible. Our model is essentially one of the second-degree price discrimination.

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 threshold level of competition at which barter disappears altogether. 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 approach is to match the manager's estimates of share of barter in sales with official statistics on 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 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 certain variables especially those related to the informal economy.

The first approach is used in Commander and Mumssen (1998),[3] Carlin et al. (2000), Brana and Maurel (1999), Marin and Schnitzer (1999). Commander and Mummsen (1998) and Carlin et al. (2000) 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

device to commit not to engage into unilateral imports.

[3]Commander and Mumssen (1998) use the second approach as well.

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. Marin and Schnitzer (1999) 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 balance. Unlike the authors using the first methodology, Guriev and Ickes (2000) find no significant relationship.[4]

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.[5] We find that barter is indeed correlated with concentration. We also test our hypotheses about structural break due to abrupt disappearance of barter when competition crosses a certain threshold. We find the critical level of concentration and show that the structural change is 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.

[4] This result suggests that the first approach may provide biased estimates. Indeed, if firm A says that firm B payer A in kind because B has not money A may be mislead since A does not have complete information on B's financial standing. See Guriev and Ickes (2000) for a detailed discussion.

[5] Caves and Marin (1992) asked firms whether they face little or substantial competition 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 provides weak evidence for positive relationship between barter and concentration.

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.[6] 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.

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 :

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

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 $F(v) = v$, $G(v) = v/2$, $v - G(v) = v/2$, $f(v)/(1 - F(v)) = 1/(1 - v)$.

As a benchmark, let us describe 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 $W^* = \int_c^1 (v - c) f(v) dv = G(1) - c + (c - G(c))F(c)$.

[6] 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.

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

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

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 $\{(p^m, 1), (0, 0)\}$.[7] 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.[8] 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 $D(p) = 1 - F(p)$.

[7] 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 $q \in (0, 1)$.

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

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.[9] 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 for re-selling or using the buyer's product.[10] 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.[11] 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

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

subject to incentive-compatibility constraints

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

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

[10] 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.

[11] 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.

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 menu of contracts: $\{(p^{mb}, 0, 1), (0, 1, 1), (0, 0, 0)\}$.*[12] *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: $c < \bar{c}$.

This assumption is satisfied if marginal cost of production is not too high. We believe that it is quite appropriate for the modern Russian economy. Most Russian firms produce well under capacity. Neither capital nor labor are fully utilized.

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 include those with $v < c$ that should be closed down in the social optimum. The inefficient buyers $v \in [0, c)$ are pooled together with the efficient ones $v \in [c, p^{mb}]$ and there is no possibility to sort them out (barter is indivisible).[13] On the other hand if the cash price is

[12] This menu is similar to a standard debt contract. The constract says: "*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 deadweight loss due to the double coincidence of wants.

[13] In equilibrium, the barter customers get a 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.

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 — 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.[14] This is an implication of indivisibility of barter. If barter payments

[14] Certainly, our model is an adverse selection model and is not very appropriate for analyzing restructuring. One should consider a moral hazard model with invest-

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 that sellers determine how much to sell for cash and for barter taking into account the 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 firms 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).[15] Each seller i is characterized by a function $T_i(q)$ — the number of customers buying no

ment 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.

[15] There are several approaches to modelling price discrimination under oligopoly. Chen (1999) studies third-degree price discrimination. 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).

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

$$(\alpha G(v^*(0)) - c)(F(v^*(0)) - T_{-i}(q))T_i(0)1(\overline{p} \geq 0)+$$

$$+\int_0^1 (p(q) - cq)d(F(v^*(q)) - T_{-i}(q)) \tag{9}$$

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.

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).[16]

We will classify equilibria by the presence of barter and then study comparative statics with regard to change in N.[17] 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 $P(Y) \geq p^*$.

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 $y_i = f(P)\left[P - \alpha G(P) - \alpha(P - G(P))(F(P) - z_{-i})/F(P)\right]$.[18] 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:

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

[16] 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.

[17] 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.

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

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

$$Z/F(p^*) = [(p^* - c)N - (1 - F(p^*))/f(p^*)] \, / \, [\alpha(p^* - G(p^*))] \quad (14)$$

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 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 $p^{nb}(N) = p^*$.

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

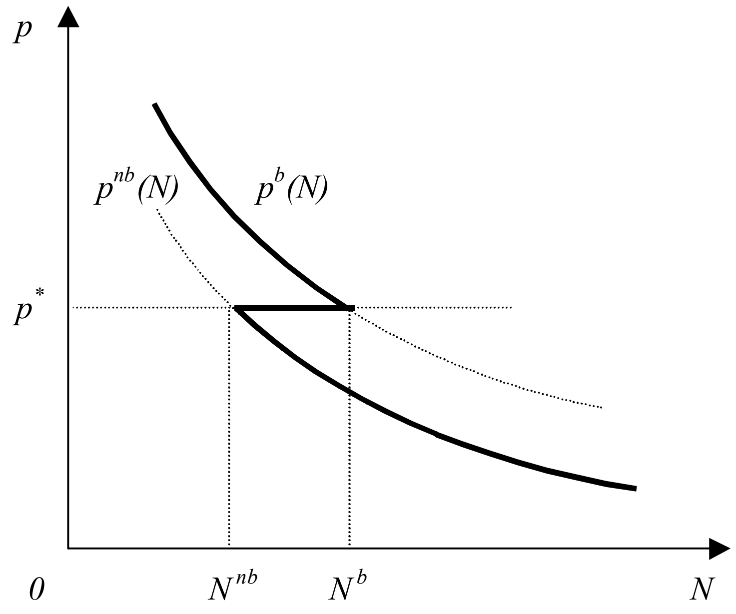

Figure 1: Oligopoly price P as function of number of sellers N.

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. Thus other sellers will have incentives to sell more for cash and less for barter.[19]

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 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

[19]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)).

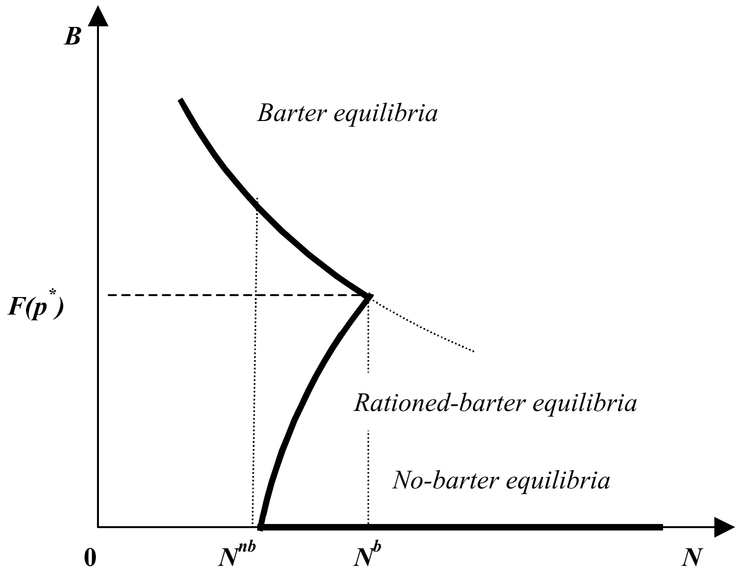

Figure 2: Share of barter sales in total sales $B = Z/(Z+Y)$ as a function of number of sellers N.

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 number of sellers, 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 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 too few firms are shut down and transaction costs are high.

3 Empirical analysis

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 full-barter equilibrium.

3.1 The data

We use the dataset 'Barter in Russian industrial firms' built in the New Economic School Research Project 'Non-Monetary Transactions in Russian

Economy'. This dataset was created by matching the surveys of managers of Russian industrial firms conducted in 1996-98 by Serguei Tsoukhlo (Institute of Economies in Transition, Moscow) with Goskomstat database of Russian firms (Federal Committee for Statistics of Russian Federation). Since Goskomstat data were most complete for 1996 and 1997 we ran regressions for 1996 and 1997 data.

The barter data include six to seven hundred firms each year. 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 987 observations: 475 (48%) in 1996 and 512 in 1997. Among these, 264 firms appeared both in 1996 and 1997.

The concentration ratios CR4 (share of four biggest firms in total sales of an industry) were calculated for 5-digit OKONKh industries (more than three hundred industries) using the Goskomstat database.[20] In our sample, some industries are not represented so that we have on average 4 firms in each industry, with up to 30 firms in some industries. Given the average CR4 in these industries is almost 40 per cent, this is quite a few. An alternative approach would be to calculate 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 goods are not substitutable.

3.2 Empirical results

The main regression we have run was an OLS regression of B (share of barter in sales) on $CR4$ (concentration ratio in the firm's industry) controlling for other variables that may explain barter. First, we controlled for the firm's size because there should evidently be economies of scale in using barter. In terms of our model, the greater the firm is, the less the transaction costs of

[20]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.

barter $1-\alpha$ are. As a proxy for size we used ls (logarithm of annual sales in thousands of non-denominated rubles). We have also tried other measures of size such as employment and got similar results.

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 shall use share of exports in sales $export$.[21] 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 set $CGI = 1$ for consumer good industries and $CGI = 0$ otherwise. In our sample, 28% firms are in consumer good industries. Unfortunately, CGI is a very crude estimate of a firm's exposure to consumer market and is in fact industry-specific rather than firm-specific.[22] Also, even producers of consumer goods are not necessarily selling directly to consumers or even to retail trade. This is why one should be careful with interpretation of regressions with CGI. However, we include CGI into regression since it can help us control for an alternative explanation of positive relationship between concentration and barter. In consumer good industries there are many small firms, and all firms receive cash from individual consumers (or retail trade). 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.

We have not included other industry dummies into regressions. The main idea of our theory is that all industries are alike and the only thing that matters is the market structure. 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, $rgasia = 1$ if the firm is based in Siberia or Far East.

[21] Certainly, it makes sense to distinguish exports by countries. We have tried to include CIS and non-CIS exports separately into regression found no significant difference. It is no wonder since non-CIS exports include exports to the less developed countries where counter-trade is common.

[22] 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 but those turned out to be insignificant.

B				
$CR4$	0.08***(0.03)	0.06**(0.03)	0.05*(0.03)	0.03(0.03)
ls		0.016***(0.004)		0.014***(0.004)
$export$		-0.13***(0.05)	-0.13***(0.05)	-0.17***(0.05)
CGI			-0.09***(0.02)	-0.09***(0.02)
$yr97$	0.04**(0.01)	0.03**(0.01)	0.03**(0.01)	0.03**(0.01)
$rgmsk$	-0.20***(0.02)	-0.20***(0.02)	-0.19***(0.02)	-0.19***(0.02)
$rgural$	0.15***(0.03)	0.14***(0.03)	0.17*** (0.03)	0.15***(0.03)
$rgasia$	0.08***(0.03)	0.07***(0.03)	0.09***(0.03)	0.08***(0.03)
$const$	0.35***(0.02)	0.10(0.07)	0.39***(0.02)	0.16**(0.07)
N	987	987	987	987
R^2	0.12	0.14	0.15	0.16

Table 1: OLS regression results. Standard errors in parentheses. *** significant at 1% level, ** 5% level, * 10% level.

The base category is European Russia except Moscow. The variable $year97$ equals 0 if the observation belongs to 1996 survey and 1 if it is from 1997 survey.

The summary statistics and the correlation matrix are shown in the Appendix A. There is no substantial multi-collinearity. The signs of pair-wise correlations are intuitive. There is indeed more barter in concentrated industries, in larger firms and in those who sell less to foreign customers and consumers. There is slightly more barter in 1997 than in 1996 (see Guriev and Ickes (1999) for the analysis of dynamic economies of scale in barter). Consumer good industries are less concentrated. Average CR4 for consumer good industries is 25 per cent which is significantly lower than in the other industries (42 per cent). There is more barter in Siberia and Urals and less barter in Moscow.

The results of the basic OLS regressions are shown in Table 1. In most specifications, share of barter positively and significantly depends on concentration. When we include CGI into regression, the effect of concentration decreases and may even become insignificant. Therefore, the evidence also corroborates the theory that there is less barter in consumer markets.[23]

[23] On the other hand, the impact of CGI and $export$ variables can also be interpreted as the effect of foreign competition (there has been a huge import penetration in Russian consumer markets).

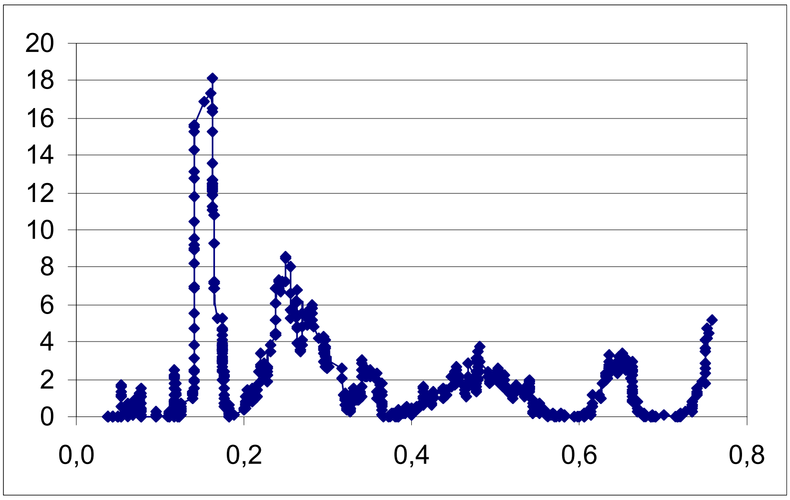

Figure 3: Andrews' statistic as a function of the suspected structural change point $\overline{CR4}$. The maximum is reached at $\overline{CR4} = 0.1616$.

In order to test for the structural break we have introduced a dummy D that takes the value of 1 if $CR4 < \overline{CR4}$ and $D = 0$ otherwise. We added a term $D * CR4$ to our regression. The coefficient at $CR4$ would then show the effect of concentration for industries with $CR4 > \overline{CR4}$. The effect of concentration for competitive industries $CR4 < \overline{CR4}$ would be equal to the sum of coefficients at $CR4$ and $D * CR4$.

To find the cutoff point $\overline{CR4}$ we have calculated the Andrews statistic (Andrews, 1993) for every $\overline{CR4} \in [0.03, 0.75]$. Figure 3 shows that the statistic reaches maximum at $\overline{CR4} = 0.1616$. At this point the statistic equals 18.11 which is well above the asymptotic critical value 6.8 calculated in Andrews (1993). There is another local maximum at $\overline{CR4} = 0.2504$ but there the statistic equals or only marginally exceeds the asymptotic critical value. Therefore the structural change is most likely to occur at $\overline{CR4} = 0.1616$. In our sample, 27% observations are in the industries with $CR4 < 0.1616$.

The results of the regressions with the structural change are presented in the Table 2. The results are fully consistent with our model. If concentration is greater than the cutoff level, the coefficient at $CR4$ is positive and significant but small (0.10). If concentration is below the cutoff level, the coefficient at concentration is positive, significant and much greater (0.93=0.83+0.10).

B				
$CR4$	0.12***(0.03)	0.10***(0.03)	0.11***(0.03)	0.10***(0.03)
$D * CR4$	0.50**(0.12)	0.54**(0.21)	0.54**(0.21)	0.83***(0.21)
ls		0.014***(0.004)	0.017***(0.004)	0.015***(0.004)
CGI				-0.10***(0.02)
$export$			-0.13***(0.05)	-0.17***(0.05)
$yr97$	0.04**(0.01)	0.03**(0.01)	0.03**(0.01)	0.03**(0.01)
$rgmsk$	-0.20***(0.02)	-0.20***(0.03)	-0.20***(0.02)	-0.18***(0.02)
$rgural$	0.15***(0.03)	0.14***(0.03)	0.14***(0.03)	0.15***(0.03)
$rgasia$	0.08***(0.03)	0.07***(0.03)	0.07***(0.02)	0.08***(0.03)
$const$	0.32***(0.02)	0.10(0.07)	0.06(0.08)	0.11(0.07)
N	987	987	987	987
R^2	0.13	0.14	0.14	0.17

Table 2: OLS regressions with structural change. Standard errors in parentheses. *** denotes significance at 1% level, ** 5% level, * 10% level.

In terms of Fig.4 (which is essentially Fig.2 redrawn in $(1/N, B)$ coordinates), the coefficient 0.10 is the slope of the barter equilibria curve, while 0.93 represents the abrupt jump from barter equilibria curve down to the no-barter equilibria curve.

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 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 with 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

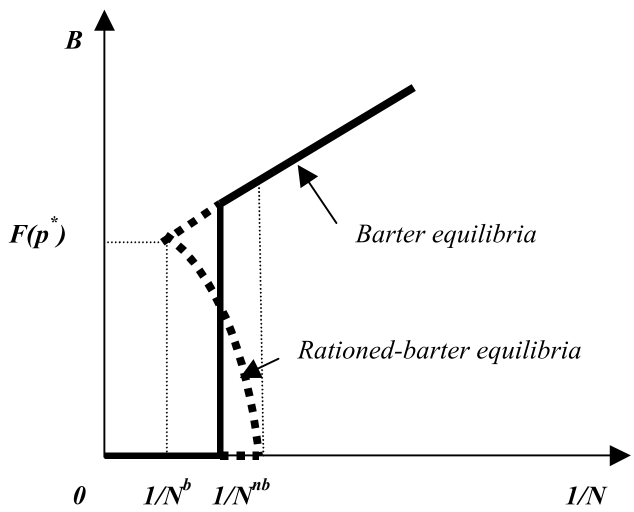

Figure 4: Share of barter in sales B as a function of concentration $1/N$. At certain concentration below $1/N^{nb}$ there occurs an abrupt jump from barter to no-barter equilibrium. At concentrations above $1/N^{nb}$, the industry is in the barter equilibrium.

equilibria under imperfect competition are usually characterized by under-production relative to the social optimum, sellers may be interested in an additional channel of sales even if this channel is costly.

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 the official statistics. The empirical analysis 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), Brown and Brown, (1998)). 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 there may be a path-dependence. 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 supply, however, is now 2 to 3 times as low as it used to be. In terms of Polterovitch (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, what our model suggests is not simply a restatement that Russia may be in a low-level equilibrium. We have shown that at some level of competition the barter equilibrium disappears and industry jumps to the no-barter equilibrium. This argument does have 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. We show that from the social planner's point of view the trade-off is as follows. Under imperfect competition, the no-barter equilibrium 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 and it does not take it into some important negative consequences of barter. Widespread barter reduces transparency in the economy which in turns leads to worse corporate governance, lower tax collection and greater corruption.

Appendix A: Tables

Table A1. Summary statistics.

Variable	Explanation	Mean	Std.Dev	Min	Max
B	Share of barter in sales	0.39	0.24	0	0.83
ls	Log sales	17.13	1.76	9.10	22.27
$CR4$	5-digit concentration	0.38	0.26	0.04	1
$export$	Share of export in sales	0.07	0.16	0	0.97
CGI	Consumer good industry	0.28	0.45	0	1
$rgmsk$	Moscow	0.10	0.31	0	1
$rgural$	Urals	0.06	0.23	0	1
$rgasia$	Siberia and Far East	0.09	0.29	0	1

Table A2. The correlation matrix (*** denotes significance at 1% level).

	B	ls	$CR4$	$export$	CGI	$year97$
B	1					
ls	0.14***	1				
$CR4$	0.11***	0.25***	1			
$export$	-0.02	0.28***	0.20***	1		
CGI	-0.18***	-0.16***	-0.28***	-0.20***	1	
$year97$	0.10***	0.00	0.02	-0.07	0.02	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

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

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 $\overline{p} \le 0$. 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 $\overline{U} \ge 0$, $q(v) \in [0, 1]$ 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

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

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 $\alpha : d\bar{c}/d\alpha = G(p^{mb})F(p^{mb})/F(p^m) > 0$; $\bar{c} \to 0$ 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.

<u>Step 1.</u> 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

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

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 $N = (1 - F(P))/\left[(P-c)f(P)\right]$ 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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