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« BARTER IN CONTEXT OF EQUILIBRIUM GROWTH MODELS»

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The paper analyses macroeconomic consequences of non-monetary exchange, namely (1) intertemporal choice between using money and barter in transactions in a specific macroeconomic environment, (2) effects of exogenous shocks and policies on this choice and dynamics of money and barter in the economy, and (3) dynamics of consumption and capital when monetary exchange and barter co-exist. It is shown that the traditional dynamic equilibrium framework is appropriate for modeling a more complex economic system which allows an agent a free choice between money and non-monetary instruments and in which this choice depends on the individual evaluation of costs and benefits.

The model can be used for evaluation of effectiveness of various policy instruments aimed at eradication of non-monetary transactions or higher monetization of GDP. E.g., it is demonstrated that tax cuts may either increase or decrease the level of barter depending on a relationship between the costs of monetary transactions and the elasticity of marginal productivity of inputs with respect to their costs. Thus, it is shown that fiscal policy is an effective instrument in fighting barter only under certain conditions.

Applied to the Russian economy, the model gives a consistent explanation of dynamics of barter and real money balances over the years of market reforms.

Introduction

We study macroeconomic consequences of non-monetary exchange, direct exchange of goods for goods or barter for short: (1) firm's intertemporal choice between using money and barter in transactions in a specific macroeconomic environment, (2) effects of exogenous shocks and policies on this choice and dynamics of money and barter in the economy, and (3) dynamics of consumption and capital when monetary exchange and barter co-exist.

We show that the traditional dynamic equilibrium framework originated by Ramsey (1928) and developed further by Solow (1957), Sidrauski (1967), and Blanchard (1985), among others, is appropriate for modelling a more complex economic system which allows an agent to make a free choice between money and barter, the system in which this choice depends only on an individual evaluation of costs and benefits. The aggregate dynamics is derived from an individual optimization, so individual decision-making on barter is linked to the total share of barter in the economy which, in turn, is a sum of individual choices. We believe that in any empirical context barter stands basically for a behavioral phenomenon, so at the aggregate level it cannot be studied without providing clear microfoundations.

As the outlined model is designed for demonstrating the basics of a general equilibrium framework, it assumes market clearing and no frictions. However, the model can be extended allowing for sticky adjustment and imperfect competition (heterogeneity of agents in market power) in line with the recent macroeconomics advances (Clarida, et al., 1999; Goodfriend and King, 1997).

Two things should be pointed out. First, this is a reduced form model. Second, while studying monetary issues, we do not model money and financial markets explicitly, so the model does not have prices or interest rates, nor does it assume savings. Money is regarded only as an amount of a means of exchange needed to carry out transactions.

With these two features, the model becomes tractable, providing a consistent explanation of dynamics of capital, barter and real money balances in response to changes in opportunity costs or aggregate demand (for discussion, see McCallum, 2001). Ceteris paribus, a change in money demand can be explained by changes in the amounts of inputs acquired for money and/or for barter. Respectively, we model barter and money as endogenous variables and imperfect substitutes. Without money as a financial asset, we are able to engage a utility-of-consumption individual

objective function and avoid the money-in-utility specification, which is important in view of the microeconomic nature of the non-monetary exchange.

Our model explains only a part, though a large part, of the issues related to barterization in the modern economies. It is well known that non-monetary forms of transactions often appear along with currency substitution as a form of adjustment to high inflation and price volatility in emerging financial markets.[1] It is argued that a rise in barter is relatively simple to understand if we think of money as a store of value, in addition to a medium of exchange (Dutta, 2000) because high inflation, i.e. money depreciation, generates a series of financial innovations and barter can be seen as one of them. This understanding of non-monetary exchange, while giving a consistent answer to the question why barter emerges and rises, soon leads us to methodological difficulties in explaining dynamics of real variables, e.g., in deriving capital and consumption timepathes given stochastic cost parameters or in studying adjustment to changes in inflation. One of the problems is how to put financial characteristics down to barter. Another one is how to link the real variables – consumption, capital, money balances, and volume of barter transactions – to these financial characteristics in a tractable, not overcomplicated way. Economic literature gives no examples of a completed monetary model allowing for non-monetary exchange. On the other hand, disregarding money as a financial asset, which is what we have done in our paper, allowed us to avoid these difficulties while bringing little distortion to the general equilibrium picture.

Two papers are worth mentioning in this respect. Engineer and Bernhardt (1991) considered coexistence of money and barter in a monetary general equilibrium optimizing framework. They show that in a decentralized economy in which households may transact in barter or in money, "the general equilibrium effect of the opportunity to barter is to reduce the value of money and, hence, to reduce the quantity of goods that can be purchased with money". However, their model is based on a modified cash-in-advance constraint and rather specific preferences which allow money and barter coexist in equilibrium only due to uncertainty (introduced through stochastic shocks to preferences), or, in case of no uncertainty, if costs of monetary and barter transactions are the same. This makes the model limited in further application.

Hayashi and Matsuri (1994) extended the model by introducing a general utility function of a sum of all quantities of desired goods and a single capital good. Here barter competes with money as a means of exchange and with capital as a store of value and is limited by the double coincidence of wants, while monetary exchange is costly due to the specific form of the cash-in-advance constraint. It is suggested that the latter appears endogenously in the sense that money balances cannot be adjusted within a period. While studying a relationship between the nominal interest rate and Pareto efficiency, they demonstrate that there is a coexistence of goods which can be acquired exclusively through money, those that acquired exclusively through barter, and goods which can be acquired through both means of exchange. They conclude that there will never be a two-way monetary exchange if the nominal interest rate is positive.

Principal assumptions

An agent produces output and maximizes utility of consumption. Unlike Hayashi and Matsuri (1994), we assume consumer goods to be homogeneous. Each moment of time an agent makes a

[1] In most cases, barter accounts for no more than small percentage of the total volume of transactions, however, the post-Soviet economies provide an example of almost thorough barterization. Estimates of non-monetary exchange in Russia in the late 1990-s vary from 30 to 80% of inter-enterprise transactions, barter was also used in paying wages and taxes. A large number of companies handled 50 – 70% and some even 100% of their sales using bi- and multilateral exchange without money (Guriev and Ickes, 1999). At the same time, M2 to the annual GDP ratio was as low as 0.08 – 0.12.

decision on allocation of output for consumption and capital accumulation. Consumption can only be acquired for money while inputs can be acquired for money and/or barter, each at different costs, so the agent also has to make a decision on what amount of inputs he buys for money and what for barter. This premise is based on empirical considerations, namely, the fact that non-monetary exchange appears mostly in the market of intermediate goods, to a great extent due to economies of scale (Bergloff and Vaitilingam, 2000).

We assume that capital goods acquired for barter and for money differ in marginal productivity because markets of monetary and barter transactions are different for each firm. First, in a given region and industry, a firm often has traditional partners (input suppliers), some of which may prefer to transact in money and some in barter. High market uncertainty and incomplete information make firms avoid risks by retaining contracts with those of the old partners who have proved to be reliable. Thus, the barter-money adjustment becomes sticky. Second, some goods are traded mostly for money because a large proportion of high-quality goods, exported items, and goods which are competitive with regards to imports, are more likely to be supplied for money. Others are acquired mostly through barter due to the existent networks and/or due to the fact that barter sometimes is used by sellers for price discrimination.

This implies that in production inputs acquired for money and bartered inputs sometimes complement and sometimes substitute for each other. This allows us to model capital as a concave function of m and b (where m and b denote amounts of inputs acquired for money and for barter respectively), which guarantees no corner solution.

Thus, we consider a two-stage production process. At a zero period, a firm is given an initial capital stock k_0. Then the firm uses k_0 and production technology f to produce output $f(k_0)$. Then, the firm allocates this output for consumption c_0 and inputs to be invested m_0 and b_0 (acquired for money and barter respectively). Next, by using technologies v_1 and v_2, the inputs are transformed into capital k_1 which will be used for further production. Herein, the production process has been described in discrete time for convenience but for further analysis we use continuous time specification.

Capital goods are used for accumulation and for replacement of depreciating capital. Production of these goods is described by input transformation functions $v_1(m)$ and $v_2(b)$. They satisfy the Inada conditions, typical of production functions, and are adjusted by network effect terms $\psi_1(\bar{m})$ and $\psi_2(\bar{b})$: $\dot{k}+\delta k=\psi_1(\bar{m})v_1(m)+\psi_2(\bar{b})v_2(b)$. Here $\bar{m}$ and $\bar{b}$ denote the average (per firm) values of inputs acquired for money and for barter; $\psi_1(\bar{m})$ and $\psi_2(\bar{b})$ capture network effects, i.e., a rise in the average productivity of respective type of inputs arising from interactions of agents in a particular form of transaction (money or barter). The latter means that the more agents are involved in barter, the lower are costs of bartering for an individual firm. The same is true of monetary transactions.

Thus, network effects are described by increasing functions $\psi_1(\bar{m})$ and $\psi_2(\bar{b})$, which for convenience are set to be distributed on interval [0, 1) and satisfy the Inada conditions. Marginal productivities in the presence of network effects in the economy as a whole is expressed by products $\psi_1(m_t)v_1'(m_t)$ and $\psi_2(b_t)v_2'(b_t)$, as is shown below. We assume that even with any network effect, marginal productivity remains decreasing, so the products are diminishing.

Since the model is non-monetary by design, the input transformation function $v_1(m)$ in no way implies money as an argument in a production function. Its specification is similar to the production function with money by Dornbusch and Frenkel (1973), however, we do not regard real balances as "a substitute for the real resources". Instead, at the beginning of the paper we gave a description of

the process of utilization of inputs and emphasized that we do not model money in an explicit way, so both m and b stand for real values of resources.

Barter and using money are associated with different costs. Costs of using money (τ) may include taxes, financial risks, generated by banks and financial markets, losses associated with inflation, and a loss from not gathering the buyer's surplus (unlike barter, selling goods for money makes price discrimination hardly possible).

The assumption concerning taxes comes from the fact that by making monetary transactions agents disclose their tax base. This does not mean, of course, that we treat barter as a black market activity, the point is that one of the incentives of using barter is that it allows firms to reduce, for example, tax outlays which are usually set as a percentage of revenues. Costs of using barter (β) include, first, those of creation exchange networks, search, and learning and, second, risks generated by barter intermediaries, if a firm uses services of such companies.[2]

Since money is not introduced in the model as a financial asset, treatment of costs associated with inflation perhaps needs to be explained in more details. In the real economy, a positive price level shock, with other things equal decreases money demand, monetary transactions become less attractive for agents who, in response, may turn to an alternative way of exchange. This event stays beyond the model. What the model captures is the inflation tax which can be measured as a fraction of the amount of inputs acquired for money.

Of course, the numerous costs of using money in reality may act simultaneously in different directions and with different lags. Moreover, some of them may be non-linear. In this example, to simplify the presentation of the idea, only one linear cost term is engaged. If they were monotonically diminishing in $\overline{m}$ and $\overline{b}$, this would produce similar results and policy implications.

Finally, we incorporate possible **effects of changes in competitiveness of the economy**. We assume that the higher is the real the exchange rate (of national to foreign currency), the cheaper are domestic goods relative to imports, therefore, the higher is aggregate demand for domestic output, which means higher competitiveness. This is captured by an increasing function of the real the exchange rate level $\rho(E) \in (0, 1)$.

We assume that the exchange rate has a stronger effect on demand for goods traded for money than for bartered goods because commodities from abroad are more likely to be imported for money. This setup implies that when demand falls (because of the national currency appreciation), a firm has to make more efforts, probably, including additional investment in raising quality, to maintain sales at the previous level. Thus, in the model, $\rho(E)$ is actually introduced as a cost term. The effect of currency appreciation in the model may be interpreted as the inverse of a productivity shock.

That the exchange rate is assumed to have a stronger effect on monetary than barter transactions, as well as the consumption-for-money setting, in our non-monetary model, in fact may be interpreted as a variation of the cash-in-advance constraint. However, money still will be used without this constraint. Our model guarantees that money will be used due to money and barter partial substitutability and due to different marginal productivities of inputs acquired for money and for barter.

Model.

The model is formulated as follows:

[2] Costs of barter may also include the loss in investments, because barter makes financial information less transparent for creditors and shareholders.

$$\max \int_0^{\infty} u(c_t)\exp(-\theta t)dt$$

$$f(k_t) = \frac{1}{\rho^2(E)} M_t + \frac{1}{\rho(E)} B_t \quad (1)$$

$$(1-\tau)M_t = m_t + c_t \quad (2)$$

$$(1-\beta)B_t = b_t \quad (3)$$

$$\delta k_t + \dot{k}_t = \psi_1(\overline{m}_t)v_1(m_t) + \psi_1(\overline{b}_t)v_1(b_t) \quad (4)$$

k0 given

Notations:

M - volume of monetary transactions,

B - volume of barter transactions,

c - consumption,

m - inputs acquired for money,

b - inputs acquired for barter,

k – capital stock,

τ - costs of using money,

β - costs of transacting in barter,

δ - capital depreciation rate,

θ - time preference rate,

$\rho(E)$ – competitiveness as a function of the exchange rate (domestic/foreign currency),

$v_1(m)$, $v_2(b)$ – input transformation functions (for m and b respectively),

$\psi(m)$, $\psi(b)$ – network effects (of money and barter respectively).

Equation (1) shows decomposition of output into that desired to be sold for money and that intended to be bartered. Expressions (2) and (3) equate demand and supply in the markets of monetary and barter transactions respectively. Equation (4) shows capital accumulation.

By substituting M and B, the problem can be rewritten in a simpler form:

$$\max \int_0^{\infty} u(c_t)\exp(-\theta t)dt$$

$$f(k_t) = \frac{1}{\rho^2(E)} \cdot \frac{m_t + c_t}{1-\tau} + \frac{1}{\rho(E)} \cdot \frac{b_t}{1-\beta}$$

$$\dot{k}_t = \psi_1(\overline{m}_t)v_1(m_t) + \psi_2(\overline{b}_t)v_2(b_t) - \delta k_t$$

Since a representative firm, by assumption, has too little market power, it considers the market values $\overline{m}_t$ and $\overline{b}_t$ to be constant. Solving a Hamiltonian, we receive:

$$\frac{u''(c_t)}{u'(c_t)}\dot{c}_t = \theta + \delta - \rho^2(E)\cdot(1-\tau)\cdot\psi_1(\overline{m}_t)\cdot v_1'(m_t) f'(k_t) + \frac{v_1''(m_t)}{v_1'(m_t)}\dot{m}_t \quad (5)$$

$$\frac{\psi_1(\overline{m}_t)\cdot v_1'(m_t)}{\psi_2(\overline{b}_t)\cdot v_2'(b_t)} = \frac{1}{\rho(E)}\cdot\frac{1-\beta}{1-\tau} \tag{6}$$

$$\dot{k}_t + \delta k_t = \psi_1(\overline{m}_t)\cdot v_1(m_t) + \psi_2(\overline{b}_t)\cdot v_2(b_t) \tag{7}$$

$$f(k_t) = \frac{1}{\rho^2(E)}\cdot\frac{m_t + c_t}{1-\tau} + \frac{1}{\rho(E)}\cdot\frac{b_t}{1-\beta} \tag{8}$$

The transversality condition ensures impossibility of a non-stationary path for the solution.

Equation (5) shows the relationship between consumption and inputs acquired for money. A similar expression linking consumption to the inputs acquired for barter can be derived:

$$\frac{u''(c_t)}{u'(c_t)}\dot{c}_t = \theta + \delta - \rho(E)\cdot(1-\beta)\cdot\psi_2(\overline{b}_t)\cdot v_2'(b_t) f'(k_t) + \frac{v_2''(b_t)}{v_2'(b_t)}\dot{b}_t \tag{5'}$$

Equations (7) and (8) represent the budget constraint. Equations (5) and (5') show that consumption increases if the marginal product of resources net of the depreciation rate is below the time preference rate, which is a variation of the Keynes–Ramsey rule. Terms $\frac{v_1''(m_t)}{v_1'(m_t)}\dot{m}_t$ and $\frac{v_2''(b_t)}{v_2'(b_t)}\dot{b}_t$ appear in the marginal product because by assuming a choice between m and b, the model permits an instant change in these variables, which should be allowed for.

Equations (5) and (5') together produce equation (6), suggesting that on the optimal path, marginal productivities of inputs acquired for money and for barter, net of costs, must be equal. Since, according to the model specification (equation (7)), network effects enter the production function, marginal productivities of each type of inputs are defined as $\psi(\overline{m}_t)v'(m_t)$ and $\psi(\overline{b}_t)v'(b_t)$. In other words, internal marginal productivity v' is adjusted to the network effects ψ. Below we will often refer to marginal productivities of inputs, net of costs τ and β, which will be called marginal net productivities for short.

As firms are assumed to be homogeneous, the market clearing conditions are $\overline{m}_t = m_t$ and $\overline{b}_t = b_t$. By combining them with the individual solution, we receive a system of equations which characterizes behavior of the economy:

$$\frac{u''(c_t)}{u'(c_t)}\dot{c}_t - \frac{v_1''(m_t)}{v_1'(m_t)}\dot{m}_t = \delta + \theta - \rho^2(E)\cdot(1-\tau)\cdot\psi_1(m_t)\cdot v_1'(m_t) f'(k_t) \tag{5a}$$

$$\frac{\psi_1(m_t)\cdot v_1'(m_t)}{\psi_2(b_t)\cdot v_2'(b_t)} = \frac{1}{\rho(E)}\cdot\frac{1-\beta}{1-\tau} \tag{6a}$$

$$\dot{k}_t + \delta k_t = \psi_1(m_t)\cdot v_1(m_t) + \psi_2(b_t)\cdot v_2(b_t) \tag{7a}$$

$$f(k_t) = \frac{1}{\rho^2(E)}\cdot\frac{m_t + c_t}{1-\tau} + \frac{1}{\rho(E)}\cdot\frac{b_t}{1-\beta} \tag{8a}$$

The transversality condition ensures impossibility of a non-stationary path for the solution.

This system describes aggregate dynamics under the assumption of the homogeneity of optimizing firms. m and b now are to be interpreted as the average per firm variables. Accordingly, the network effects ψ1 and ψ2, which enter the individual problem as functions of the aggregate values, now, in equilibrium, refer to the effects of existing networks in the economy as a whole.

In theory, a multiplicity of solutions is possible. This depends on the form of products $\psi_1(m_t)v_1'(m_t)$ and $\psi_2(b_t)v_2'(b_t)$. If we assume that the slope of (speed of change in) the marginal net productivity curve for one type of input is always higher than that for another input, then equation (6a) gives a unique solution for m=m(b) and the system has a unique solution. This simplification, while it may be debatable from the empirical viewpoint, does not bring any irrelevance to the analysis.

Adjustment of steady state to macroeconomic shocks

In the steady state all variables of individual choice are constant: $\dot{k} = \dot{m} = \dot{b} = \dot{c} = 0$. Thus, we obtain:

$$\psi_1(m) \cdot v_1'(m)\, f'(k) = \frac{\delta + \theta}{\rho^2(E)(1-\tau)} \qquad (9)$$

$$\rho(E)(1-\tau) \cdot \psi_1(m) \cdot v_1'(m) = (1-\beta) \cdot \psi_2(b) \cdot v_2'(b) \qquad (10)$$

$$k = \frac{1}{\delta}[\psi_1(m) \cdot v_1(m) + \psi_2(b) \cdot v_2(b)] \qquad (11)$$

$$f(k) = \frac{1}{\rho^2(E)} \cdot \frac{m + c}{1-\tau} + \frac{1}{\rho(E)} \cdot \frac{b}{1-\beta} \qquad (12)$$

Equation (9) can be rewritten for barter:

$$\psi_2(b) \cdot v_2'(b)\, f'(k) = \frac{\delta + \theta}{\rho(E)(1-\beta)} \qquad (9')$$

Adjustment to changes in costs of using money (τ). To understand adjustment of the steady state to changes in costs of using money (τ), we differentiate equation (10) with respect to τ, bearing in mind that functions $\psi_1(m_t)v_1'(m_t)$ and $\psi_2(b_t)v_2'(b_t)$ are assumed to be diminishing in m_t and b_t, respectively. We obtain (known signs below the functions):

$$-\rho(E)\psi_1(m)v_1'(m) + \rho(E)(1-\tau)[\psi_1(m)v_1'(m)]'\frac{dm}{d\tau} = (1-\beta)[\psi_2(b)v_2'(b)]'\frac{db}{d\tau} \qquad (13)$$

$$(+) \qquad (-) \qquad (-)$$

Effect of changes in costs of using money (τ) on volume of monetary transactions (m). If it were assumed $dm/d\tau > 0$, it would require $db/d\tau > 0$ as well but this violates the steady state equation (9) and, therefore, is not possible. Thus, $dm/d\tau < 0$.

Effect of changes in costs of using money (τ) on barter (b). To show this effect, we rewrite equation (13) in the following form:

$$\frac{d\left[\rho^2(E)(1-\tau) \cdot \psi_1(m)v_1'(m)\right]}{d\tau} = \rho(E)(1-\beta)[\psi_2(b)v_2'(b)]'\frac{db}{d\tau} \qquad (14)$$

The sign of $db/d\tau$ is determined by the sign of the derivative of marginal net productivity of inputs acquired for money with respect to τ (the left hand side of the equation (14)).

Let us consider the effects of a rise in costs of monetary transactions (for example, an increase of taxes) on the marginal net productivity of inputs acquired for money. First, the increase of taxes raises marginal productivity $\psi_1(m_t)v_1'(m_t)$, as the optimal volume of monetary transactions in acquiring inputs becomes lower; second, it means a rise in costs of monetary transactions, which

has a negative effect on marginal net productivity. These effects work in opposite directions and the strongest one determines whether barter rises or declines in response to a change in the costs of using money.

Thus, interpretation of the equation (14) becomes straightforward. A positive left hand side means that higher costs of monetary transactions make marginal net productivity of inputs acquired for money higher (the first effect outweighs the second one), so the firm is better off replace a part of barter by monetary transactions until marginal net productivities of both types of inputs become equalized again. As a result, we receive $db/d\tau<0$. Alternatively, we receive $db/d\tau>0$ when the second effect outweighs the first one.

The conditions determining the sign of derivative $db/d\tau$ can be derived via the elasticity of marginal productivity of inputs acquired for money with respect to τ. To show this, we rewrite equation (13) as:

$$\frac{1-\tau}{\tau}\rho(E)\left[\psi_1(m)v_1'(m)\right]\cdot\left(\sigma^m_{MP,\tau}-\frac{\tau}{1-\tau}\right)=(1-\beta)\left[\psi_2(b)v_2'(b)\right]'\frac{db}{d\tau} \qquad (15)$$

(+) (-)

known signs below the functions. Here $\sigma^m_{MP,\tau}$ is the elasticity of marginal product of inputs acquired for money with respect to costs of monetary transactions:

$$\sigma^m_{MP,\tau}=\frac{d\left[\psi_1(m)v_1'(m)\right]}{d\tau}\cdot\frac{\tau}{\psi_1(m)v_1'(m)}$$

We see that

$$\frac{db}{d\tau}>0 \quad \text{when } \sigma^m_{MP,\tau}<\frac{\tau}{1-\tau} \quad \text{and}$$
$$\frac{db}{d\tau}<0 \quad \text{when } \sigma^m_{MP,\tau}>\frac{\tau}{1-\tau} \qquad (16)$$

Effect of changes in costs of using money (τ) on capital stock (k). Given $dm/d\tau < 0$ which has already been proved, if we assume $dk/d\tau > 0$, it requires $db/d\tau > 0$ as well. However, this would violate the steady state condition (9') and, therefore, is not possible. Thus $dk/d\tau < 0$.

Conclusions and policy implications. So, in the steady state, increasing costs of using money reduces the levels of capital and monetary transactions, while their effect on barter is contingent on the costs of monetary transactions and the elasticity of marginal productivity of inputs acquired for money with respect to costs of using money. If this elasticity is low compared to the costs, there is a positive relationship between the volume of barter transactions and the costs of using money. If the elasticity is high, the relationship is negative.

The negative effect of costs of using money on capital and inputs and thereby, on the amount of money needed for transactions, is quite clear. A possible rise in barter in response to increasing costs of using money follows from the fact that bartered and traded for money inputs have been considered to be imperfect substitutes.

What are the policy implications of this finding? Fiscal policy (apart from the fiscal discipline enforcement) is not always the effective instrument for fighting barter because elasticity of marginal productivity of inputs can hardly be estimated. So, for example, the efficiency of any additional tax cut aimed at eradication of non-monetary transactions or higher monetization of GDP is debatable as it may produce an opposite result. Fiscal measures seem to be appropriate for fighting barter only

in extreme cases when the relationship between the elasticity and the costs of using money is obvious. For instance, if the tax rate is very high, equation (13) suggests that a tax cut reduces barter, thus fiscal policy is efficient. However, if the tax rate is relatively low, the elasticity evaluation is advised before engaging fiscal instruments.

Implications for financial markets are also straightforward. If financial markets function well, a relatively small rise in anticipated losses may have a pure contracting effect, depending on the elasticity of marginal productivity of monetary inputs with respect to costs of monetary transactions. But if financial markets are seriously ill, a further decline associated with mounting anticipated losses from using money could make agents turn more to barter which would, to a certain degree, prop up the abruptly falling output.

The model suggests that a historical record of barter rising as inflation is falling (in Russia) might be explained by a relatively high elasticity of marginal productivity of inputs acquired for money.

Adjustment to changes in costs of barter (β) is analyzed in a similar manner and produces similar results (τ and β are symmetric according to the model design). Increasing costs of barter, such as costs of search, entering barter networks, additional quality control, and other individual costs, i.e. those which do not arise from the network effect, decrease the steady state levels of capital and barter transactions: $dk/d\beta < 0$, $db/d\beta < 0$. The effect of barter costs on money (quantity of intermediate goods traded for money) is contingent on the initial costs of barter and the elasticity of marginal productivity of bartered inputs with respect to costs of barter transactions:

$$\frac{dm}{d\beta} > 0 \quad \text{when} \quad \sigma^{b}_{MP,\beta} < \frac{\beta}{1-\beta} \quad \text{and}$$
$$\frac{dm}{d\beta} < 0 \quad \text{when} \quad \sigma^{b}_{MP,\beta} > \frac{\beta}{1-\beta} \qquad (17)$$

Effect of changes in the exchange rate (E) on the volume of monetary transactions (m): The negative signs of the first derivative of $\psi_1(m_t)v_1'(m_t)$ and $\psi_2(b_t)v_2'(b_t)$ do matter. By differentiating equation (10) with respect to ρ=ρ(E), we obtain (known signs are below the functions):

$$(1-\tau)\cdot\psi_1(m)v_1'(m) + \rho(E)(1-\tau)[\psi_1(m)v_1'(m)]'\frac{dm}{d\rho} = (1-\beta)[\psi_2(b)v_2'(b)]'\frac{db}{d\rho} \qquad (18)$$

(+) (–) (–)

If we assume $dm/d\rho < 0$, it requires $db/d\rho < 0$, thus, $dk/d\rho < 0$. However, this violates steady state equation (9) and, therefore, is not possible. Thus, $dm/d\rho > 0$.

Effect of changes in the exchange rate (E) on barter (b): The effect depends on the elasticity of marginal productivity of inputs acquired for money with respect to the exchange rate. The dependence can be shown by the expression (which is just a variation of equation (18)):

$$(1-\tau)[\psi_1(m)v_1'(m)]\cdot\left(1+\sigma^{m}_{MP,\rho}\right) = (1-\beta)[\psi_2(b)v_2'(b)]'\frac{db}{d\rho} \qquad (19)$$

(+) (–)

where $\sigma^{m}_{MP,\rho} = \frac{d[\psi_1(m)v_1'(m)]}{d\rho}\cdot\frac{\rho}{\psi_1(m)v_1'(m)}$

is the elasticity of marginal product of inputs acquired for money.

Currency depreciation (an increase in ρ(E)), as was shown earlier, raises the steady state level of monetary transactions and, therefore, reduces the marginal productivity of inputs acquired for money. Thus, $\sigma^{m}_{MP,\rho}$ is negative. Equation (19) suggests positive relationship between the volume of barter transactions and the exchange rate when marginal productivity of inputs acquired for money is highly sensitive to changes in the exchange rate. On the contrary, it suggests negative relationship between them if marginal productivity is low sensitive:

$$\frac{db}{d\rho} > 0 \quad \text{when} \quad \sigma^{m}_{MP,\rho} < -1 \quad \text{and}$$
$$\frac{db}{d\rho} < 0 \quad \text{when} \quad \sigma^{m}_{MP,\rho} > -1 \qquad (20)$$

If influence of the exchange rate on marginal productivity of inputs acquired for money is strong enough, then depreciation followed by a rise in domestic aggregate demand, makes a firm increase the volume of monetary transactions to the level where a firm finds it reasonable to use barter to complement money. However, if the influence of the exchange rate is weak, barter falls.

Effect of changes in the exchange rate (E) on capital stock (k). With $dm/d\rho > 0$, already proved, $dk/d\rho < 0$ requires $db/d\rho < 0$ which, however, violates steady state equation (9'). Therefore, $dk/d\rho > 0$.

So, in the steady state, if marginal productivity of inputs acquired for money is highly sensitive to the exchange rate, depreciation of the national currency increases competitiveness (ρ) and thus the levels of capital stock, monetary transactions, and barter. However, if this marginal productivity is not sufficiently sensitive, depreciation reduces the steady state level of barter.

Brief summary of findings

1. In steady state, an increase in **costs of using money** reduces the level of monetary transactions (in acquiring inputs) and the level of capital, while it can influence the level of barter in different directions. If elasticity of marginal productivity of inputs acquired for money with respect to costs of monetary transactions is rather low relative to the costs of money, the level of barter is increasing in the costs of monetary transactions.
2. In steady state, an increase in **costs of barter** reduces the level of barter transactions and the level of capital, while it can influence the level of monetary transactions (in acquiring inputs) in different directions. If elasticity of marginal productivity of bartered inputs with respect to costs of barter is rather low relative to the costs of barter, the level of monetary transactions is increasing in the costs of barter. This effect is symmetric to the effect of changes in costs of money.
3. **Depreciation of national currency** increases the steady state values of monetary transactions and capital, as it increases aggregate demand for domestic productions. Nevertheless, depreciation can have different effects on the steady state volume of barter transactions. It increases barter if marginal productivity of inputs acquired for money is highly sensitive to the exchange rate. However, if this marginal productivity is not sufficiently sensitive, depreciation reduces the steady state level of barter.

Model application: barter in Russia

The model gives a consistent explanation of barter dynamics in the Russian economy over the years of market reforms. This dynamics is shown in figure 1. It is evident that the proxies for barter and the real the exchange rate, i.e., the inverse of the competitiveness index are probably positively related. The relationship between barter and the possible cost terms – corporate taxes (VAT and profits tax), loans extended to the real sector, debt instruments (GKO and OFZ, bonds for short) outstanding, inflation, rate of return on bonds, and loan rates – is also consistent with the model.

Elimination of price and other restrictions implemented in 1992, pushed the economy toward a new equilibrium which implied a higher level of barter because the costs of using money became higher (due to inflation and, later, as is described below, the liquidity squeeze) and the costs of barter became lower (as the institute of barter mediation was developed). As the economy was moving along the stationary path toward that new steady state, barter was persistently growing.

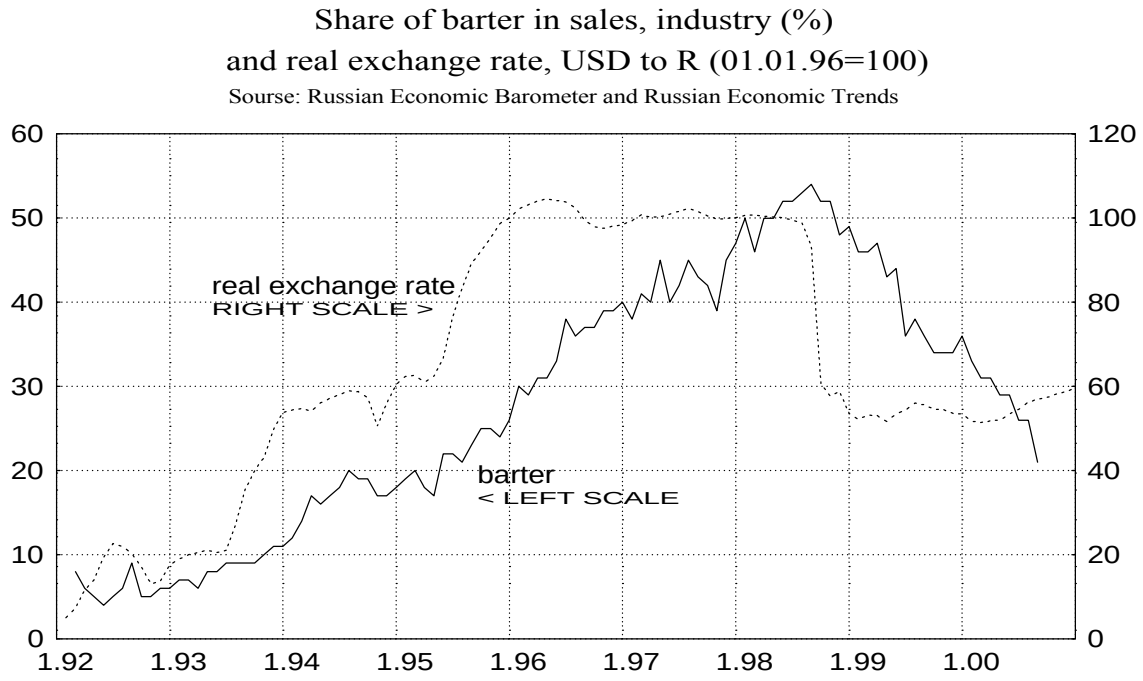

Fig. 1.

Barter started to grow along with non-payments in response to the cash shortage in the summer of 1992 but fell in September with the unanticipated inflationary shock. The monetary expansion in the spring – summer of 1992 had propped up the output, steadily declining after the liberalization, for a few months. The external money supply was so high that enterprises were able to reduce barter.

Then barter continued to grow slightly due to high inflation and market volatility, remaining at a relatively low level, because the real interest rate – a measure of opportunity costs of using money – was negative or near zero. A few months after the real interest rate turned to a positive value (October – November 1993), the growth of barter accelerated. The temporary exchange rate shock of October 1994 followed by a reduction in the real interest rates is associated with a slight fall in barter which continued to grow simultaneously with the real interest rate driven by the slowing inflation and, later, by the government debt market. Some slowdown in barter in 1997 may be explained by a "saturation" effect, that is a consequence of diminishing marginal productivity, as barter reached a relatively high share in transactions.

Growth in barter continued until the August crash in 1998. The crash followed by a permanent the exchange rate shock changed the steady state again: a jump in the dollar-rouble rate made aggregate demand switch to domestic goods, which should be interpreted as a positive demand shock. Thus, as the real exchange rate fell sharply – twice in a moment, the elasticities of marginal products of inputs with respect to the competitiveness were rather low, so the new steady state barter become smaller, which is consistent with the model. The effect was probably strengthened by better tax enforcement from the earlier 1999. So the continuous post-crisis decline in barter can be interpreted as movement towards that new steady state.

If the macroeconomic situation does not change, barter will continue to decline until it achieves the new steady state level. A possible appreciation of the rouble, if it is sufficiently significant, may move the economy to a new steady state in which barter level will be higher, so the decline of barter may slow down.

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