

Sticky Prices versus Sticky Information: A Test Using a Natural Experiment in the Russian Real Estate Markets

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May 17, 2006

Abstract

A natural experiment in the Russian real estate markets is used to test different theories of price formation. Following the ruble devaluation in August 1998, behavior of apartment prices differed markedly in different Russian cities. In cities, in which prices were denominated in American dollars, they fell slowly over time. In cities, in which prices were quoted in Russian rubles, their dollar-equivalents fell sharply together with the exchange rate, stayed low for two to three years, and then recovered rapidly when economy picked up. Such behavior is found to be consistent only with a sticky-price model with backward-looking agents. Models based on forward-looking agents and sticky information do not find support.

JEL Classification: E31, E32

Keywords: Sticky prices, adaptive expectations, housing market.

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1 Introduction

The Russian financial crisis of August 1998, as any other major disruption of economic activity, has produced a number of observations interesting to academic economists, which go far beyond the analysis of just the Russian economy. One such striking observation is behaviour of prices for apartments in different Russian cities. As noted first by Gennadiy Sternik from the Russian Guild of Realtors, prices of apartments in cities, where they have been traditionally quoted in rubles, the local currency, have behaved quite differently from the prices in the cities, where people have been accustomed to denominate real estate prices in American dollars.¹ Specifically, in the "dollar" cities, prices fell quite slowly and recovered slowly when the economy started to recover a couple of years later. In the ruble cities, by contrast, the dollar-equivalents of the prices fell dramatically on impact, in September of 1998, together with the exchange rate, and stayed lower than in the dollar cities throughout the period of low income. Thus, a purely nominal difference has led to big divergence in the relative price of apartments in the two groups of cities.

This paper uses this observation as a natural experiment to answer a more general question about price behavior. For several decades now, macroeconomists have argued whether market prices are consistent with competitive equilibrium predictions, or whether they are subject to some sort of nominal rigidity. A survey of the vast literature on sticky prices can be found, for example, in Taylor (1999); a more recent competing hypothesis on sticky information is described in Mankiw and Reis (2002, 2003). Hence, here we test different models, described in this literature, which potentially could explain such behavior of prices, and find that only the model based on sticky prices and adaptive expectations is consistent with the data. A model with flexible prices cannot be in line with these observations, because such a model would predict identical behavior of prices in all cities. We also show that the model with forward-looking price-setters also does not do well, as it fails, similarly to some previous findings in the literature, to replicate the acceleration of inflation at times of high income. Finally, the model with sticky information also finds weaker support with the data, although is not outright rejected.

The approach we take in this paper is the following. We assume that the two groups of cities, the ones, in which apartment are priced in dollars, and the ones, in which apartment are priced in rubles, are identical in all respects with the exception of the currency used as a unit of account in the real estate market. The tradition to use dollars in some of the cities was established during the high-inflation period of the early 1990s and continued on when inflation came down. Other than this difference, all behavioral functions should be the same. We then estimate these behavioral equations, searching for one model, which would explain the observed different patterns of prices as an equilibrium in both groups of cities. We find that the same behavioral equations of a sticky-price model with adaptive expectations, with similar coefficients, explain equally well the very different price patterns.

Of course, a note of caution is due. First, secondary real estate markets in Russia cannot be

¹Articles and data collected by Sternik describing this behavior can be found at <http://www.realtymarket.ru>

considered fully representative, because they consist of non-sophisticated sellers and buyers, for whom an apartment sale may be one of the few time in their lives, when they try to sell something at all. Second, standard models of sticky prices usually refer to pricing of goods and services, while apartments can also be viewed as assets, bought for investment purposes, and not only for the purposes of obtaining a flow of utility. These notions imply that one should be careful in generalizing this result to business cycle models of developed market economies. What is very striking and valuable for business cycle research, however, is that we find strong evidence of sticky prices even in the situation of a disastrous crisis with high inflation, thus casting doubt on a frequently confronted view that sticky prices may be a reasonable hypothesis only in quiet times, when relative prices do not show big movements.

The rest of the paper is organized as follows. Section 2 describes the behavior of apartment prices and introduces the reader to the general conditions in the Russian economy in 1998-2001. Section 3 gives some basic description of the data used. Then, Section 4 shows a simple sticky-price model with forward-looking and then adaptive expectations and demonstrates that only the adaptive expectations version is consistent with the data. Section 5 builds a model based on sticky information and shows the results of corresponding empirical tests, which do not lend support to this specification. Section 6 then demonstrates that the flexible model fails as well. Section 7 concludes.

2 Facts and Discussion

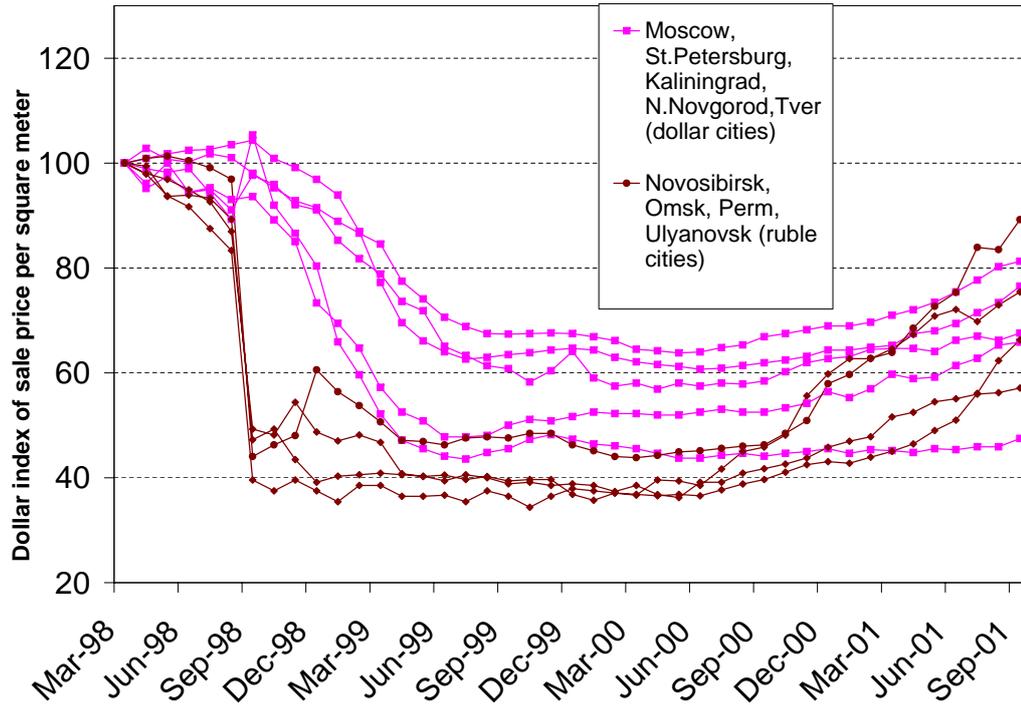
In August of 1998, Russia has suffered a disastrous financial crisis, which lead to a double real devaluation of the ruble and a big fall in the real income. Inflation, which was virtually subdued during the period of the "crawling peg" over 1995-1998, spiked up to a monthly 36% in September, totaled 84% in all of 1998, and then slowly fell to about 18% in 2001. The exchange rate, held at about 6.2 rubles per dollar until the devaluation, went to 16 rubles per dollar in September, and then gradually climbed to about 30 rubles per dollar by the end of 2001. Thus, the original devaluation was much stronger than the increase in the price level.

The real income, in turn, fell gradually by about 20%, reaching the trough in the first half of 1999, and then recovering to pre-crisis levels by the end of 2001.

The behavior of apartment prices in nine Russian cities is shown in Figure 1. These prices represent the dollar equivalents of the averages per square meter on the secondary market, with March 1998 normalized to 100.² In Kaliningrad, Nizhniy Novgorod, Moscow, St.Petersburg, and Tver apartment have been priced in dollars, while in Novosibirsk, Omsk, Perm, and Ulyanovsk the pricing has been traditionally done in rubles. This purely nominal difference between the pricing practices appears to have a huge effect on the dynamics. Thus, in the dollar cities, the fall of prices has been much slower and smaller in magnitude than dollar-equivalents of the prices in the ruble cities, giving immediate support to the hypothesis that the prices have been rigid in the currency,

²In Russia, it is customary to own apartments, rather than rent them.

Figure 1: Russian cities: behavior of apartment prices



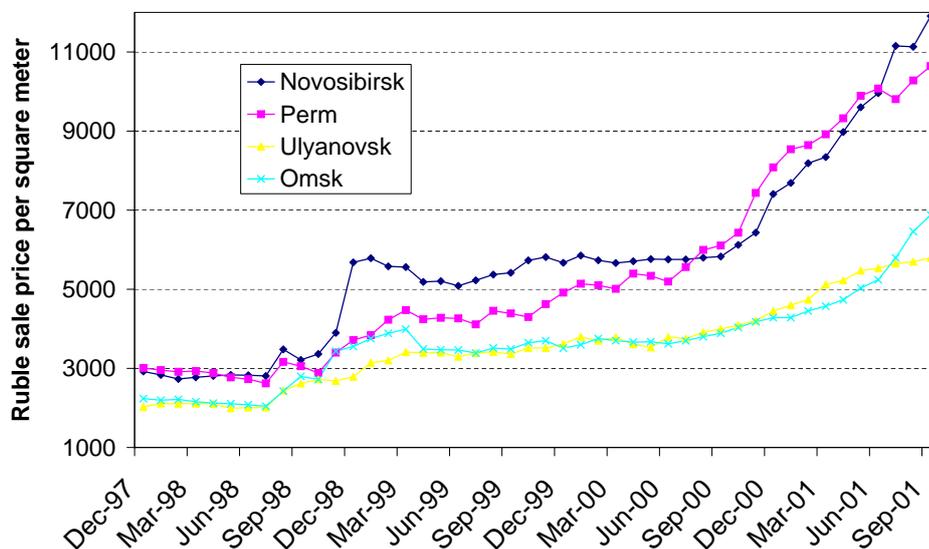
Source: The Russian Guild of Realtors.

in which they are quoted. The dollar prices in the dollar cities have not changed very much on impact, nor did the ruble prices in ruble cities. Instead, the dollar-equivalents of the ruble prices fell immediately simply because the nominal value of the ruble fell almost threefold between August and September 1998. Then, a large disparity between apartment prices in the two groups of cities endured until at least 2001.

In order to see better, how prices behaved in the ruble cities, we also plot their prices in rubles in Figure 2. It is easy to see that in three out of four cities the crisis and the large devaluation did not produce any visible immediate effect: prices grew smoothly. Only in Novosibirsk was there a large jump in prices in December 1998, by about 50% (with a reduction in later months). But even with this jump, the price growth between August and December was half as big as the nominal depreciation of the ruble.

We posit that the divergence between apartment prices in these two groups of cities was caused solely by usage of different currencies for quotation of price. The use of the U.S. dollar as a unit of account was quite wide-spread in Russia in the 1990s and continues to be still - this phenomenon was labeled "foreign currency pricing" by Levina and Zamulin (2006). The primary hypothesis is that dollars were a more convenient unit of account at times of high inflation in the early 1990s,

Figure 2: Behavior of apartment prices in ruble cities (in rubles)



Source: The Russian Guild of Realtors.

because dollar prices could be kept unaltered for a longer period of time. Then, as inflation fell, in some sectors and cities sellers switched back to Russian rubles, while in others the tradition of quoting prices in dollars endured, showing hysteresis. It is noteworthy that when the dollar is used as a unit of account, the actual transaction does not have to be in dollars - in fact, it is illegal in Russia to transact in currencies other than rubles. However, the denomination of prices in a certain currency can make prices sticky in that currency, since other sellers pay attention to the current market prices when determining how much money to ask for their apartment.

Of course, the distribution of the dollar-pricing and ruble-pricing cities can be non-random, which sheds doubt on whether the above observation can be used as a true natural experiment. After all, the listed dollar cities do seem to be more westernized in general, so they may be subject to different dynamics than the more provincial ruble cities. Therefore, the denomination of prices is potentially a highly endogenous variable. However, these fears do not disturb us very much. First of all, the dynamics of income or CPI inflation in different cities do not show any variations that can explain different apartment price behavior within those cities. Besides, we do use regional, as well as national income figures in regressions that follow, so income effects should be caught. More importantly, Levina and Zamulin (2006) have shown that after a period of high inflation, an

economy or an individual market can be stuck in a dollar-pricing equilibrium, in which no seller would be willing to unilaterally switch to ruble pricing even after inflation is subdued, for fears of deviating far from the competitors' prices with fluctuations of the exchange rate. Thus, we believe that different cities are simply caught in different equilibria after the high inflation of early 1990s, and hence the denomination of prices is no longer as endogenous as may seem. This idea allows treatment of this episode as a natural experiment.

Although data for later years are now available, we consciously limit ourselves to the 1998-2001 period. This period represents a clear business cycle swing, in which income fell sharply after the crises, and then recovered to the original levels. But more importantly, at the end of 2001, relative apartment prices in different cities, as can be seen in Figure 1, approximately reached the pre-crisis parity, and then the dynamics did not differ as much. Hence, it is interesting to study the period of great divergence, and see whether one model with the only difference of nominal denomination can fit the data in all cities. We did run regressions on extended data set, as a robustness check, and found qualitatively similar results.

3 The data

The primary available data include monthly average prices of a square meter of apartments sold in the secondary market in nine Russian cities between March 1998 and September 2001. These prices are quotes from advertisements collected by realtors, so in principle, they can differ from the actual transaction prices, since additional bargaining could take place once the seller and the buyer met. These data have been collected by Gennadiy Sternik from the Russian Guild of Realtors.

Unfortunately, no reliable data exist on the volume of the market in these cities during the period, although the volume of secondary market transactions can be found for Moscow, but not starting in 1998. Hence, in later analysis, we will have to assume that the volume of the market is related to income and apartment prices through a stable demand relationship.

We also take seasonally adjusted monthly figures for monetary income both for all of Russia and for individual regions, from Rosstat (formerly Goskomstat), Russia's primary statistics agency.

4 Sticky price models

The way we approach this paper is that we assume that people's behavioral functions are identical in all cities, and that one model should explain behavior of prices in all of these cities. In this section we consider two models based on sticky prices, one with rational expectations, and one with adaptive expectations.

The sticky price model is based on Calvo (1983), in which it is assumed that the sellers adjust their price at a stochastic rate α . Of course, the Calvo model can be applied here only as an approximation, since in the basic form it was designed to study price formation of a continuously sold good. In the secondary apartment markets, however, the sale of an apartment is a one-time

event, and the seller may be keeping the price constant until the apartment is sold. Thus, the best way to think about the application of the Calvo model here is that in each period share α of the apartments are being sold, and an equal number of new sellers come in, who set a different price. For the primary market, apartments are a standard product, so their price is adjusted up and down on regular basis.

We assume that in each period there is an unobservable instantaneous "desired price" $p_t^\#$ (given in logarithm) common to all. This is the price that maximizes profits of firms in the primary market and maximizes utility of sellers on the secondary market, who desire to sell their apartment fast on the one hand, and earn as much money as possible on the other. We do not model this maximization problem explicitly, but rather assume the following standard condition for the desired price:

$$p_t^\# = p_t^a + \beta(q_t - \bar{q}) = p_t^a + \beta q_t, \quad (1)$$

where p_t^a is the (observed) average apartment price level, q_t is the (unobserved) total demand for apartments at time t , and \bar{q} is the demand at the natural level of total income, here normalized to zero in logarithm. Expression (1) says that the instantaneously optimal price for each apartment relates to the average market price and excess demand. At the time of high demand, a seller would prefer to quote a price somewhat above the average, at the time of low demand - below average. Hence, the parameter β denotes "real price rigidity" in the sense of Ball and Romer (1990): the parameter shows how much the optimal price depends on the real demand as opposed to prices of the competitors.

The second expression of the model is the total demand on the apartment markets. We need this equation primarily because we do not have data on the volume of transactions in each period, so instead we deduce this volume through a demand function. It is assumed that the total demand for apartments is CES in the total income and relative price, and is thus given in logarithmic form by

$$q_t = y_t - \gamma(p_t^a - p_t), \quad (2)$$

where y_t is the total income of the households in the city, while p_t is the overall price level.

The third equation shows the behavior of the apartment price level p_t^a . Since on average each period α sellers adjust their prices, then in each period the change in price level will equal this fraction of price adjusters times the difference between the current price level and the "reset" price b_t - the price set by the seller, who gets a chance to adjust at time t . Thus, inflation in the apartment market is determined by:

$$\Delta p_{t+1}^a = \alpha(b_{t+1} - p_t^a). \quad (3)$$

The change of price is thus the reset price as of the current period less the price level inherited from the previous period.

To close the model and produce testable implications, we need an expression for the reset price b_t . The way this price is determined heavily depends on the type of expectation, which the sellers have. Here we consider two possibilities: forward-looking (rational) expectations, and adaptive expectations. Let us consider both in turn.

4.1 Forward-looking expectations

In case the sellers are rational and forward-looking, they set the price keeping in mind expectations of the future desired prices. A standard result in this literature is that the reset price equals a weighted average of the future desired prices (for example, this result can be obtained from minimizing the present value of future quadratic losses from price non-optimality as in Ball, Mankiw and Romer (1988), or directly out of maximizing profit, as in Kimball (1995)):

$$b_t = \alpha \sum_{s=0}^{\infty} (1 - \alpha)^s p_{t+s}^{\#}. \quad (4)$$

From here, taking differences, we obtain the following expression for the evolution of the reset price:

$$\Delta b_{t+1} = \alpha(b_{t+1} - p_t^{\#}). \quad (5)$$

Expression (5) allows us to derive a testable equation in terms of observable variables. For that, take the first difference of (3), substitute (5) in, expand $b_{t+1} - p_t^{\#} = b_{t+1} - p_t^a + p_t^a - p_t^{\#}$, and use (3) again to eliminate b_{t+1} . Then, use (1) and (2) to eliminate $p_t^{\#}$ and obtain

$$\Delta \pi_{t+1}^a = -\frac{\alpha^2 \beta}{1 - \alpha} y_t + \frac{\alpha^2 \beta \gamma}{1 - \alpha} (p_t^a - p_t), \quad (6)$$

where $\pi_{t+1}^a \equiv p_{t+1}^a - p_t^a$. Thus, we obtain results on the change of the inflation rate of the apartment prices. This result reflects that in a sticky-price environment, inflation should be high but decelerating at times of high demand, and, correspondingly, low but rising when demand is weak.

The equation (6) can be tested for each city individually or for all combined. It is important to realize, however, that the nominal variables have to be denominated in the currency, in which the apartments are actually denominated in that city. The only nominal variable in (6) is the change of inflation on the left-hand side, so we make sure that the inflation is taken in the right currency. The regressors, on the other hand, are all real variables.

In the two types of cities, the estimated coefficients need not be the same, because the parameter α , governing the frequency of price adjustment, is endogenous to the rate of inflation (Ball et al. 1988, Kiley 2000). This coefficient is expected to be greater in the ruble-pricing cities, as ruble inflation has been high throughout this period. Since both coefficients in (6) are positive functions of α in absolute value, we expect them to be bigger as well in the ruble cities.

The results are reported in Table 1. These results are obtained using the seasonally adjusted CPI and national real income data from Rosstat, the Russian federal statistical commission. The income figures are not detrended, because in years 1998-2001 there was no trend to speak of; rather, income seems to represent a swing of business cycle, consisting of the 1998 crises and the later recovery.

The results in Table 1 demonstrate that the rational expectations sticky price model does not describe the data well. Most importantly, the coefficient in front of income is positive, not negative, in the regressions for ruble cities. This result is commonly obtained in tests of sticky-price models: inflation is found to be rising in times of boom, contrary to the prediction of the model. At the same time, for dollar cities the coefficient has a correct negative sign.

Table 1: Testing the rational expectations model

Dependent variable $\Delta\pi_{t+1}^a$			
City	Constant	y_{t+1}	$p_t^a - p_t$
<i>Panel regressions:</i>			
All dollar cities (fixed effects)		-0.050 (0.046)	-0.055 (0.027)
All ruble cities (fixed effects)		0.128 (0.079)	-0.163 (0.055)
<i>Individual dollar cities:</i>			
Moscow	0.126 (0.110)	-0.017 (0.021)	-0.012 (0.011)
St.Petersburg	0.419 (0.122)	-0.064 (0.026)	-0.038 (0.009)
Kaliningrad	0.390 (0.386)	-0.035 (0.079)	-0.067 (0.026)
Nizhny Novgorod	0.417 (0.372)	-0.033 (0.080)	-0.080 (0.044)
Tver	0.361 (0.160)	-0.050 (0.037)	-0.046 (0.016)
<i>Individual ruble cities:</i>			
Novosibirsk	0.192 (0.297)	0.184 (0.114)	-0.306 (0.147)
Omsk	0.127 (0.468)	0.037 (0.107)	-0.102 (0.045)
Perm	-0.277 (0.411)	0.196 (0.123)	-0.182 (0.080)
Ulyanovsk	-0.097 (0.227)	0.092 (0.066)	-0.109 (0.044)

Even more disastrous is that the relative apartment price uniformly enters negatively and in most cases significantly, while the predicted sign is positive.

The problem with predicted falling inflation at times of high income is normally fixed by switching to either some form of adaptive expectations (Gali and Gertler 1999), or by switching to sticky-information models, recently proposed by Mankiw and Reis (2002, 2003). We now turn to adaptive expectations, and will consider sticky information in Section 5.

4.2 Adaptive expectations

The simplest method to introduce adaptive expectations is to simply assume that the sellers expect the desired price in the future to be the same as the desired price today. This assumption gives a very simple solution to the behavior of prices: reset price is simply replaced by the desired price, for which there is a clear expression. The only problem is that such behavior, unlike the rational expectations one, is difficult to reconcile with trend ruble inflation, which was present in Russia in

the period under study, at least after the August 1998 crisis. A way to fix that problem is then to assume that each seller, when setting the price, adds an increment of the current inflation rate in the country to the reset price, otherwise obtained from this form of static expectations.

Thus, the expressions for the reset price, combined with (1) are

$$b_t = p_t^a + \beta q_t \quad (7)$$

in dollar cities, and

$$b_t = p_t^a + \beta q_t + \frac{1}{\alpha} \Delta p_{t+1} \quad (8)$$

for ruble cities. Thus, it is assumed that there is no trend inflation in dollars, while each seller in a ruble city adds the current inflation times $1/\alpha$ - the length of time during which her price is expected to be fixed.

The testable equations then become, after combining the above two equations with (2) and (3),

$$\Delta p_{t+1}^a = -\alpha\beta\gamma(p_t^a - p_t) + \alpha\beta y_{t+1} \quad (9)$$

for the dollar cities, and

$$\Delta p_{t+1}^a - \Delta p_{t+1} = -\alpha\beta\gamma(p_t^a - p_t) + \alpha\beta y_{t+1} \quad (10)$$

for the ruble cities. These equations are quite intuitive. The apartment prices grow when their relative price is low and when the demand is high. They fall when the opposite is true.

Once again, the coefficient for the ruble cities are expected to be greater, as sellers must be adjusting their prices more frequently in an inflationary environment.

The results of the estimation of (9) and (10) are shown in Table 2. These results are reported both using the national Russian real income, and regional real incomes of the corresponding cities. Although the regional incomes may seem to be a better variable to use, the quality of measurement of regional income, especially at monthly frequencies, is very questionable. Hence, we report the results obtained both with the national, which is supposedly easier to measure, and the regional incomes. The results do not seem to depend greatly on this choice of income measure.

It is immediately seen that the model with adaptive expectations does much better than the model with rational expectations. Indeed, for panel estimation, all of the coefficients are significant and have the correct sign. For individual cities, coefficients are not always significant, but the sign is always as predicted. As expected, the coefficients for ruble cities are all bigger in absolute value than those for dollar cities.

5 Sticky information

Mankiw and Reis (2002, 2003) propose an alternative explanation for the apparent slow response of the aggregate price level to changes in the economic environment. They assume that individual sellers face some costs of obtaining information necessary for price formation. The existence of

Table 2: Testing the adaptive expectations model

Dependent variable Δp_{t+1}^a for dollar cities, $\Delta p_{t+1}^a - \Delta p_{t+1}$ for ruble cities						
City	Using national income			Using regional income		
	Constant	y_{t+1}	$p_t^a - p_t$	Constant	y_{t+1}	$p_t^a - p_t$
<i>Panel regressions:</i>						
All dollar cities (fixed effects)		0.410 (0.123)	-0.110 (0.058)		0.177 (0.066)	-0.129 (0.059)
All ruble cities (fixed effects)		0.419 (0.088)	-0.209 (0.051)		0.215 (0.058)	-0.235 (0.064)
<i>Individual dollar cities:</i>						
Moscow	-1.170 (1.540)	0.363 (0.319)	-0.093 (0.081)	0.669 (0.356)	0.200 (0.155)	-0.147 (0.080)
St.Petersburg	-1.784 (1.656)	0.475 (0.352)	-0.072 (0.066)	0.179 (0.293)	0.342 (0.216)	-0.049 (0.080)
Kaliningrad	-0.546 (1.585)	0.239 (0.342)	-0.139 (0.065)	0.582 (0.229)	0.038 (0.134)	-0.165 (0.065)
Nizhny Novgorod	-2.029 (1.537)	0.554 (0.343)	-0.110 (0.059)	0.476 (0.206)	0.195 (0.130)	-0.128 (0.061)
Tver	-1.422 (1.376)	0.437 (0.303)	-0.153 (0.056)	0.522 (0.165)	0.147 (0.107)	-0.164 (0.056)
<i>Individual ruble cities:</i>						
Novosibirsk	-0.858 (0.666)	0.354 (0.172)	-0.206 (0.114)	0.892 (0.505)	0.255 (0.114)	-0.282 (0.158)
Omsk	-1.448 (0.744)	0.443 (0.190)	-0.166 (0.067)	1.042 (0.405)	0.400 (0.154)	-0.349 (0.136)
Perm	-1.705 (1.117)	0.612 (0.374)	-0.298 (0.180)	0.588 (0.545)	0.197 (0.221)	-0.180 (0.169)
Ulyanovsk	-1.045 (0.606)	0.387 (0.170)	-0.228 (0.083)	0.568 (0.364)	0.116 (0.099)	-0.192 (0.122)

such information costs implies that an individual price-setter updates her information occasionally, from time to time, rather than in a continuous manner. After buying a new portion of information, the seller resets the whole trajectory of the price for her product, which will be in force until the next resetting. The sticky information model is thus a multi-period generalization of Fischer (1977) model with predetermined prices.

To be specific, assume that every period only a fraction α of sellers updates their information about macroeconomic conditions and adjusts optimal, or "desired" price paths. At time t , the price-setter who updated her information s periods ago for the last time, sets the price

$$b_t^s = E_{t-s} p_t^\# \quad (11)$$

where $E_{t-s}(\cdot)$ denotes the expectation operator conditional on the information available at time $t-s$ and $p_t^\#$ is the "desired price" at time t . Then the aggregate price level on the market for

apartments at time t is

$$p_t^a = \alpha \sum_{s=0}^{\infty} (1 - \alpha)^s b_t^s. \quad (12)$$

Substituting (11) into (12) and using (1), we obtain

$$p_t^a = \alpha \sum_{s=0}^{\infty} (1 - \alpha)^s E_{t-s}(p_t^a + \beta q_t), \quad (13)$$

which, in turn, can be transformed to the following equation for π_t^a :

$$\pi_t^a = \frac{\alpha\beta}{1-\alpha} q_t + \alpha \sum_{s=0}^{\infty} (1 - \alpha)^s E_{t-s}(\pi_t^a + \beta \Delta q_t) \quad (14)$$

where, according to (2),

$$q_t = y_t - \gamma(p_t^a - p_t). \quad (15)$$

Taking the first difference of q_t , we get

$$\Delta q_t = \Delta y_t - \gamma(\pi_t^a - \pi_t). \quad (16)$$

Substituting (15) and (16) into (14) we obtain

$$\pi_t^a = \frac{\alpha\beta}{1-\alpha} (y_t - \gamma(p_t^a - p_t)) + \alpha \sum_{s=0}^{\infty} (1 - \alpha)^s E_{t-s-1}(\pi_t^a + \beta(\Delta y_t - \gamma(\pi_t^a - \pi_t))). \quad (17)$$

We can interpret (17) as a stochastic difference equation for the determination of the relative, or real price for the apartments, $p_t^a - p_t$, where the processes for π_t and y_t are exogenously given.

Assume that π_t and y_t are stationary and follow independent AR(1) processes. Then we can solve the equation (17). The solution takes the form:

$$p_t^a - p_t = \sum_{s=0}^{\infty} (\phi_s y_{t-s} + \psi_s \pi_{t-s}) \quad (18)$$

where coefficients $\{\phi_s\}_{s=0}^{\infty}$ and $\{\psi_s\}_{s=0}^{\infty}$ are expressed in terms of structural parameters of the model and the parameters of underlying autoregression processes for y_t and π_t . The exact expressions can be found using the method of undetermined coefficients, and the parameters in front of contemporaneous income and inflation are:

$$\phi_0 = \frac{\frac{\alpha\beta}{1-\alpha}}{1 + \frac{\alpha\beta\gamma}{1-\alpha}} > 0 \quad (19)$$

and

$$\psi_0 = -\frac{1}{1 + \frac{\alpha\beta\gamma}{1-\alpha}} < 0. \quad (20)$$

The signs of these coefficients are intuitive. Increase in income stimulates those who update information today to adjust their price upward, hence the positive sign. A surprise increase in overall

Table 3: Testing the sticky information model: fixed-effect panel-data regressions

Dependent variable $p_{i,t}^a - p_t$				
	Using national income		Using regional income	
Regressor	All dollar cities	All ruble cities	All dollar cities	All ruble cities
$p_{i,t-1}^a - p_{t-1}$	-0.450 (0.342)	1.004 (0.077)	-0.730 (0.398)	1.041 (0.074)
$p_{i,t-2}^a - p_{t-2}$	1.270 (0.324)	-0.095 (0.075)	1.337 (0.361)	-0.125 (0.082)
y_t	1.584 (0.306)	0.593 (0.144)	0.341 (0.086)	0.236 (0.074)
y_{t-1}	-0.374 (0.165)	-0.210 (0.160)	-0.108 (0.062)	-0.103 (0.073)
y_{t-2}	-0.688 (0.240)	-0.064 (0.131)	-0.049 (0.065)	0.004 (0.068)
π_t OR $\pi_t - \varepsilon_t$	-3.331 (0.828)	-0.681 (0.116)	-3.312 (0.922)	-1.009 (0.080)
π_{t-1} OR $\pi_{t-1} - \varepsilon_{t-1}$	0.587 (0.209)	0.315 (0.191)	0.500 (0.215)	0.378 (0.155)
π_{t-2} OR $\pi_{t-2} - \varepsilon_{t-2}$	0.038 (0.153)	0.336 (0.217)	-0.278 (0.116)	0.160 (0.164)

inflation, on the other hand, leaves the predetermined apartment prices of this period behind the overall price level.

In the case of dollar pricing, the analogue of (18) is

$$p_t^a - p_t = \sum_{s=0}^{\infty} (\phi_s y_{t-s} + \psi_s (\pi_{t-s} - \varepsilon_{t-s})) \quad (21)$$

where the lags of the overall inflation in ruble terms in the second sum are replaced with the corresponding lags of the overall inflation in dollar terms, which equals to the former minus the rate of ruble depreciation, ε_t .

We can test equations (18) and (21) by estimating the following panel-data regressions:

$$p_{i,t}^a - p_t = \sum_{l=1}^2 a_l (p_{i,t-l}^a - p_{t-l}) + \sum_{l=0}^2 (b_l y_{i,t-l} + c_l \pi_{t-l}) + \eta_t \quad (22)$$

for ruble cities and

$$p_{i,t}^a - p_t = \sum_{l=1}^2 a_l (p_{i,t-l}^a - p_{t-l}) + \sum_{l=0}^2 (b_l y_{i,t-l} + c_l (\pi_{t-l} - \varepsilon_{t-l})) + \eta_t \quad (23)$$

for dollar cities separately and estimating $\hat{\phi}_0 = \hat{b}_0$ and $\hat{\psi}_0 = \hat{c}_0$. The estimated regressions are shown in Table 3.

The table shows that the sticky information model enjoys only weak support of econometric tests. The most important problem is that the coefficients differ markedly between dollar and ruble

Table 4: Testing the flexible price model: fixed-effect panel-data regressions

Dependent variable $p_{i,t}^a - p_t$	
Cities	y_t
All dollar cities (national income)	-0.453 (0.134)
All ruble cities (national income)	1.089 (0.078)
All dollar cities (regional income)	-0.199 (0.082)
All ruble cities (regional income)	0.803 (0.049)

cities. The coefficients in front of lagged relative price are of opposite sign, in one case both being significantly different from zero. The coefficients in front of current inflation are of the same sign but very different between dollar and ruble cities, which suggests that the sticky information model can't be the unified model that explains differences between the two cities. At the same time, most of the coefficients are of the expected sign, and hence the model cannot be rejected outright.

Intuition also suggests that sticky information is unlikely to account for the differences observed between the two groups of cities. The prices in this model are completely flexible, and information was likely to be the same in all cities. Hence, we would expect that prices to behave identically as well. After all, it is hard to believe that in cities where apartments are priced in once currency people noticed the financial crisis, while people in the other cities did not.

6 Flexible prices

If the prices were flexible then we would expect the price level to be equal to the desired price at all times, and hence demand for the apartments to remain at a constant level, \bar{q} . This level is equal to the demand at the natural level of total income. Thus, under flexible prices, equation (2) takes the form:

$$q_t = y_t - \gamma(p_t^a - p_t) = \bar{q} \quad (24)$$

Equation (24) can be tested by regressing the relative, or real price for apartments on the real income:

$$p_t^a - p_t = a + by_t + \eta_t. \quad (25)$$

The estimated fixed-effect panel-data regressions are reported in Table 4. We see that the coefficient of real income is positive and significant for ruble cities while negative and significant for dollar cities. Obviously, this finding is not compatible with equation (24), which implies that both the sign and the value of the real income coefficients must be the same in both cases. Hence, the flexible price assumption has to be dismissed outright, as seems intuitive from Figure 1.

7 Conclusions

Behavior of apartment prices in different Russian cities following the devaluation in August 1998 lends support to the hypothesis that prices on this market are sticky, and price formation is backward-looking rather than forward looking. In the cities, where the apartments are commonly priced in dollars, apartment prices responded slowly to the falling income, so they turned out to be relatively high comparing to the overall price level. In the cities, where apartments are priced in rubles, dollar equivalents of these prices fell dramatically on impact in September 1998, and remained low through the next three years. They then recovered faster when income picked up. Both common sense and formal testing performed in this paper show that such behavior is not consistent with flexible prices, nor it is consistent with sticky information models: clearly, people in all cities had the same information about what was happening. What was going on is that every apartment offered on the market was priced according to the average price on the market at the time and the price remained fixed for a certain time period. Hence, the prices changed slowly in the currency, in which they were denominated. The rapid devaluation of the ruble, on the other hand, forced a dramatic fall in the dollar-equivalent of the ruble-denominated apartment prices.

Rejection of the sticky-information model seems natural, because it is difficult to imagine that the crisis of the magnitude that took place in Russia in 1998 could be unnoticed by apartment sellers. Indeed, the sticky-information model was designed to describe quieter times, in which information updating is costly. Hence, perhaps the strongest result of our paper is that sticky price models seem to be immune to the same critique - prices remained sticky despite of large changes in the economic environment. This result implies that it may be premature to replace the sticky-price paradigm with sticky information one fully.

Acknowledgements

The authors thank Gennadiy Sternik from the Russian Guild of Realtors for providing the data and insights. They also thank seminar participants at the New Economic School, the Central European University, and European Economic Association meetings for useful comments.

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