EXCHANGE RATE AND PRICES IN AN ECONOMY WITH CURRENCY SUBSTITUTION: THE CASE OF BELARUS

by

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Abstract

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This paper explores the possibility that such aspect of currency substitution as posting prices for domestically sold goods in foreign currency units can facilitate exchange rate surprises pass-through into the overall price level. Using simple denomination of international trade-like model, it is shown that for a domestic firm it could be reasonable to post prices in foreign exchange, when prices are pre-set one period ahead and exchange rate is uncertain. The presence of firms quoting prices in foreign currency engenders price level responsiveness to unexpected exchange rate changes. This implication is tested on Belarusian monthly data for three aggregate price indices – consumer price index, producer price index, and agrifood price index. Estimation results suggest that the patterns of pass-through into these indices are different. Exchange rate surprises seem to produce significant and prolonged effect on consumer price index, significant immediate effect on producer price index, and insignificant effect on agrifood price index. Under the circumstances of exchange rate targeting and price

liberalization in Belarus, these differences may lead to inflation rates divergence across heterogeneous groups of commodities. The estimated pass-through is strongly associated with proxies for currency substitution.

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GLOSSARY

Currency substitution. Situation when domestic monetary unit is replaced by its foreign counterpart in some of three traditional capacities of money – store of value, medium of exchange, or unit of account

DCP. Domestic currency pricing

Dollarization ratio. Ratio of foreign currency deposits to broad domestic monetary aggregate (M2)

FCP. Foreign currency pricing

Hysteresis in currency substitution. Situation when temporary changes in inflation rates (or other related variables) engender permanent shifts in currency substitution

Invoicing currency. The currency in which actual payment is made

Pass-through. Transmission of exchange rate fluctuations into domestic prices or import prices

Price-setting currency. The currency in which prices are posted

SEATS. Signal extraction in ARIMA time series

TRAMO. Time series regression with ARIMA noise, missing observations and outliers

Chapter 1

INTRODUCTION

Economic instability often engenders the lack of credibility to the domestic monetary authority and domestic currency. It is observed that in many emerging market economies currencies of developed countries, in the first turn the US dollar, substitute the home currencies in the three traditional roles of money. This phenomenon is labeled as "currency substitution" or sometimes "dollarization". The extent of currency substitution differs from country to country, being relatively high for emerging market economies.

Transacting in foreign currency can have serious implications for domestic economy; e.g., it can aggravate inflationary consequences of fiscal imbalances[1]. In an analogous way, foreign currency denominated assets, serving in a store of value capacity, can have even more policy implications than carrying out transactions in foreign exchange[2].

The displacement of the domestic currency in a unit of account capacity, on the contrary, was not paid much attention to so far. In this research we propose to consider some of the implications of price-setting in foreign currency for domestic economy. In a highly unstable environment firms often find it convenient to post prices in relatively more confident currency, which can be seen as a part of currency substitution phenomenon. Calvo and Vegh (1992) note that pricing in the foreign exchange often antecedes the displacement of the home currency in transacting. Zamouline (2001) notices that pricing in "notional

[1] That is the point by Bufman and Leiderman (1992), among others.

[2] See the survey article by Calvo and Vegh (1996).

units", widespread in some post-Soviet economies, is the manifestation of currency substitution either.

The focus of the current research is exchange rate pass-through into the domestic prices when some of these are set in the foreign currency. There is a wide stream of studies in which theorists try to model the bottlenecks that allow exchange rates affect prices. Recent investigations reveal that denomination of imports and exports is a crucial determinant of the degree of exchange rate pass-through into imported and exported goods' prices.

If, however, individuals and legal entities in these countries find it rational to quote domestic prices in foreign currency, then exchange rate movements can directly affect the prices of nontradables also. Several authors note that currency substitution can stipulate foreign inflation transmission through the exchange rate movements (Rogers, 1990; McKinnon, 1982). Au contraire, this research analyzes whether exchange rate fluctuations could be the source of price changes.

Presumed transmission mechanism is similar to that proposed by pass-through theorists. The occurrence of pricing in foreign currency means that part of domestic prices is directly quoted in foreign exchange and hence is exposed to exchange rate changes provided that prices are not fully flexible. Since posting prices for domestically sold goods in foreign currency is a form of replacement of domestic money in role of a unit of account, we can label this as currency substitution.

The empirical challenge is to estimate the changes in the effect of the exchange rate on domestic prices and to consider if these changes have much in common

with currency substitution trends in Belarus[3]. The presumed correlation between pricing in foreign currency and the exchange rate pass-through into domestic prices calls for time-varying coefficients estimation. In this research we employ rolling regression and state-space model econometric technique, the latter being especially useful when estimated relation might undergo changes within the observed period.

A rationale behind the choice of price-setting currency is explored by a number of papers on exports' pricing in foreign currencies (Bacchetta and van Wincoop, 2001; Devereux and Engel, 2001; Friberg, 1996; Giovannini, 1988). The common finding of the recent general equilibrium models is that a country with relatively less stable monetary unit will have large fraction of imports priced in foreign currency and its import prices exposed to the exchange rate movement to larger extent (Bacchetta and van Wincoop, 2001; Devereux and Engel, 2001). The motivation of domestic firms may be quite similar to that of firms trading internationally. Thus, there are no in general reasons why, when exporters find it optimal to set their prices in foreign exchange, domestic firms deter from following same strategy.

The crucial assumption of the model is that prices are set in advance. Friberg (1996) provides the following rationale for assuming pre-set prices in foreign currency: "… it would be prohibitively expensive to most markets to reoptimize offer prices every time the exchange rate changes." By the same token, exchange rate pass-through literature presumes that prices exposed to the exchange rate may not fully respond to the currency price fluctuations because of costly price adjustment mechanisms. Non-zero menu cost can explain price stickiness, as well as specific forms of price controls, that do not allow firms to promptly respond

[3] There can be consumption switching effect of the exchange rate changes, when relative prices in the economy change because of the price of domestic currency movements, but we do not consider these issues in the present research though they may be important.

with prices. Findings of this paper as well as the entire set of results of the exports denomination models, depend on this assumption.

It is important to note, however, it is not always larger domestic inflation that drive firms out of domestic unit of account domain. The model with one period ahead preset prices suggests that some times weaker currency may substitute harder currency as a unit of account. This plausibility, albeit abstract, point out that it could be misleading to talk about currency substitution in a unit of account capacity of money in terms of the Gresham's law. Network effects, shifts in demand or cost parameters may render pricing in a given currency units undesirable.

The Republic of Belarus had its ups and downs of currency substitution during the past decade of independent history. However, it always remained high so that the IMF classifies the country as "highly dollarized" (IMF, 2000). Moreover, the government allows some prices to be legally quoted in the foreign currency, which makes the country the appropriate testing ground in the context of the present research. The pattern of exchange rate pass-through into Belarusian domestic price level could be helpful in the view of recent declaration of authorities to embark on exchange rate targeting.

The rest of this paper is organized as follows. Chapter 2 provides a brief survey of the related literature. Chapter 3 describes the institutional settings in Belarus in what concerns currency substitution issues. Chapter 4 gives a theoretical justification for the empirical work, presenting some aspects of individual choice of price-setting currency by a firm, and then exploring the possibility of exchange rate pass-through into the overall price level in an economy with currency substitution. In Chapter 5 we attempt to estimate the effect of the exchange rate surprises on the price indices in Belarus, and then consider how this effect relates to currency substitution. Chapter 6 concludes.

Chapter 2

RELATED LITERATURE

There is an immense array of literature related to this research. On the one hand, numerous attempts to model and evaluate exchange rate pass-through into domestic and import prices were launched. Recent researches reveal that the question of great concern for the degree of pass-through is the currency in which importers and exporters post their prices. On the other hand, currency substitution theorists investigate the motives that drive agents to substitute foreign money for domestic money. This chapter reviews these strands of literature.

Exchange rate pass-through

Movements in exchange rate directly affect consumer prices in an open economy via several channels. First, some foreign finished goods are included into the consumer bundle; as a result, prices of these goods and their domestic substitutes change in accord with exchange rate fluctuations. Second, domestic suppliers can use imported inputs in production. Hence, their costs are exposed to exchange rate changes. Third, foreign demand for domestic commodities varies in the price of domestic currency. Prices of exported goods therefore depend on the exchange rate. Moreover, as Dornbusch (1986) states, changes in commodity prices through cost of living tend to fuel wages and industrial materials costs in manufacturing, thus opening up another channel of exchange rate influence onto

domestic prices[4]. Exchange rate pass-through literature studies how exchange rate fluctuations affect domestic and import prices, and inflation[5].

Much of the discussion on exchange rate pass-through into consumer prices stems from the Friedman (1953) argument for the flexible exchange rates. Friedman (1953) notices that in the presence of price stickiness flexible exchange rates allow relative prices between countries adjust in response to shocks and consumer expenditures shift between the goods. However, in recent decades there appeared a large number of researches motivated by the observed incomplete pass-through of exchange rate into consumer and import prices. Engel (2002) points out that the argument presented above relies on two assumptions: (1) goods prices are invariant in currency of the producer of the good; (2) there is significant pass-through of exchange rate change to the buyer of the good. Therefore, in the presence of sticky prices it makes the crucial difference what is the pricing currency of imports and exports[6].

Pricing in the currency of consumer (local currency pricing) is one plausible explanation why pass-through is low. In the case of local currency pricing exchange rate fluctuations simply marks the deviations from the purchasing power parity, since domestic prices of imported goods remain unchanged in terms of the home currency units, while the price of the home currency shifts upward or downward[7].

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[4] Direct and indirect channels of the exchange rate pass though are discussed in Lafleche (1997).

[5] The most often cited review of pass-through literature is the one by Goldberg and Knetter (1997). Some recent models of the exchange rate pass though into consumer prices are surveyed in Engel (2002).

[6] Bacchetta and van Wincoop (2001) present the evidence of negative relationship between pass-through and proportion of imports invoiced in the importer's currency, for the sample of 7 developed countries.

[7] Devereux and Engel (2000), Corsetti and Pesenti (2001) argue that for the deviations from the law of one price to be minimized the optimal monetary policy in this case is to fix the exchange rate.

Another strand of literature sets up the models that explain why pass-through might be low in the case of producer currency pricing. If importers do not engage in price discrimination between domestic and foreign markets, and the prices of imported goods are set in the home currency of producers, values of imported goods prices vary one to one with exchange rates[8]. However, transportation and distribution costs may amount to a large portion of a delivered final good price, as theorists after Obstfeld and Rogoff (2000) point out. As soon as these costs are incurred in the home currency, exchange rate fluctuations do not change import and consumer prices greatly. Furthermore, as Engel (2002) note, domestic suppliers substitute away from imported inputs in production if imports turn out to be more expensive due to exchange rate changes. The common notion is that in the presence of price stickiness the crucial determinant of the degree of pass-through is the fraction of delivered imports priced in the producer currency. The two polar cases, one where all products are priced in the producer home currency, and the other one where all prices are set in the consumer home currency, correspond to the cases of complete and zero pass-through respectively. The denomination strategies of the firms matter for the degree of exchange rate pass-through.

Quantitative estimation of exchange rate pass-through into domestic prices and inflation is attempted by means of different econometric techniques. Ordinary least squares (Woo, 1984; Gagnon and Ihrig, 2001), weighted least squares (Choudri and Hakura, 2001), panel data (De Gregorio and Borensztein, 1999; Goldfajn and Werlang, 2000), vector auto regression (McCarthy, 1999), error

[8] Optimal price discrimination between home and foreign markets is commonly referred to as "pricing to market". Pricing to market studies concentrate on whether and how the markup adjusts to exchange rate changes. A domestic firm posting prices optimally whether in the foreign or in the home currency, will not deliberately discriminate consumers paying in either currency, if prices are set one period ahead. However, if prices are pre-set more than one period ahead, the story is more complicated.

correction models (Beaumont et al, 1994; Garcia and Resterpo, 2001), state-space models (Darvas, 2001) are among them[9].

Empirical investigations suggest that pass-through is more in developing and emerging market economies than in the OECD members (McCarthy, 1999; Choudri and Hakura, 2001; Takagi and Yoshida, 2001). Several researchers intend to test the hypothesis after Taylor (2000) that pass-through is negatively correlated with inflationary environment. The idea is that in an economy with credibly low inflation firms are more reluctant to change prices frequently in accord with their input prices fluctuations, since they perceive changes in cost as transient. Results of the cross-country comparisons, however, are not so far self-evident. For example, Choudri and Hakura (2001) obtained high and significant correlation between pass-through coefficients and mean annual inflation for the sample of 71 countries, whilst Gagnon and Ihrig (2001) similar estimates for 11 industrial economies are low and insignificant.

Less empirical work was done in the field of testing time stability of exchange rate pass though. Garcia and Restrepo (2001) employ rolling correlation coefficients between the Chilean rates of inflation and depreciation for both moving and expanding samples in 1986 – 2001[10]. Both sets of coefficients show some instability within the time period; obviously, the one for moving sample is much more unstable.

Several authors, testing the stability of pass though over time, implement the Chow breakpoint test-like algorithms. Takagi and Yoshida (2001), for example, analyze the difference that the Asian currency crisis of 1997 had on exchange rate pass-through into Japanese import and export prices. These researchers compare

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[9] The listing of the papers is mostly due to Garcia and Resterpo (2001).

[10] These authors use inflation rates calculated on the basis of a "narrower-than the CPI price index" (core inflation) instead of CPI based inflation rates. The core inflation index does not count for the costs of regulated services, which are said to be sensitive to changes in exchange rate. Since sensitivity of that sort is seen as a manifestation of currency substitution in a sense defined above, we are motivated to use CPI index on the contrary.

pass-through coefficients obtained for the entire time span with those obtained for pre-crisis time period. The difference between the two sets of coefficients is not large for the whole sample, but in individual cases the coefficients breaks were present. In an analogous fashion, McCarthy (1999) reproduces the estimation procedure for a shorter sample period and compares the results with those processed for the entire observed period[11]. It is observed that in the 1980s and the 1990s pass-through coefficients for analyzed countries somewhat decreased. Employing the dummy variable for an appropriate subperiod, Gagnon and Ihrig (2001) also observe declining degree of pass-through in the 1990s. Exemplification of that sort can be carried on.

An alternative strategy for determining the evolution of exchange rate pass-through over time is the time-varying coefficient estimation. This approach could be helpful in that it allows researcher to obtain quantitative results on to what extent the pass-through is different between any two dates within the sample. On the other hand, it requires estimating larger number of coefficients thus making some researchers reluctant to employing such technique. Parsley (1995) challenges fixed pass-through coefficients framework by pointing out the possibility of intertemporal linkages between pass-through coefficients. Nominal rigidities do not let past pass-through fade away immediately. Hence, it could be reasonable to employ time-varying parameter estimation, prescribing autoregression to pass-through coefficient. Results of commodity level study by Parsley (1995) seem to confirm time-variability hypothesis. Darvas (2001) apply more complicated procedure to estimate how pass-through coefficients for perspective EU members evolved over time. He uses two equations simultaneous time-varying parameter estimation and finds that pass-through coefficients greatly change over time. Furthermore, their evolution patterns are different across

[11] McCarthy (1999) employs the error correction framework and estimates pass-through as cumulative response in domestic CPI corresponding to 1% increase in the exchange rate. The sample consists of 9 developed countries.

sample countries. Darvas (2001) concludes that both exchange rate regime and the volatility of exchange rate may matter for the degree of pass-through. Exchange rate targeting, as Darvas (2001) findings suggest, may facilitate reducing inflation[12].

The story behind recent exchange rate pass-through investigations is that the denominations of exports and imports play crucial role in determination of the extent of pass-through. The decision of an exporter in which currency to post price is analyzed in denomination of international trade studies.

Currency denomination of international trade

The export denomination literature endogenizes the exporter's choice of price-setting currency. This strand of literature was first motivated by the observed disparity between countries' international trade volumes distribution and the denomination structure of international trade[13].

The first generation models tackle this problem in a partial equilibrium setting[14]. The common notion is to consider the expected profit-maximizing exporter that is choosing among the currencies in which to denominate the price of his product at the foreign market, and sets price respectively. Plausible denomination strategies are to set the price either in the importer's currency or in the exporter's home currency[15]. The exporting firm may be a monopolist, as in Ahtiala and Orgler (1995), or engage in Bertrand competition, as in Friberg (1996 and 1998); what matters is that the firm faces residual demand function. The crucial

[12] Nadal-De Simone (2000) builds the time-varying parameter small open economy empirical model in order to be able to forecast inflation in Chile. It is found that the contribution of the exchange rate into the explanation of Chilean inflation rates varies greatly over time: the appropriate coefficient lies between 0.47 and 0.

[13] Friberg (1996) presents a detailed example for the case of Sweden. Donnenfeld and Haug (2001) demonstrate the difference in patterns of the US import volumes and its denomination.

[14] Examples of this stream of literature are Giovannini (1988), Ahtiala and Orgler (1995), Friberg (1996 and 1998), and others.

[15] Friberg (1996) extends the analysis so that it is allowed for a firm to price in the third country currency, but the general principles are similar.

assumptions behind this set of models are that the firm must set price before the exchange rate is known, and the demand realizes after the exchange rate is known. The exporter maximizes expected profits in terms of its home currency; and demand is described in terms of consumer's home currency. The exchange rate is stochastic with mean value known in advance.

Price stickiness of the described form implies that firm is uncertain about realized profits. If it decides to set price in the exporter's currency, then the realized quantity and cost of production are not known. If the price is set in the importer's currency, then only price in terms of the exporter's currency is uncertain, while demands as well as costs are known in advance. Hence, exporter's realized profits are a linear increasing function of exchange rate, when he is pricing in the importer's currency. If he is pricing in his home currency, then the form of the realized profit function in exchange rate depends on the characteristics of underlying cost and demand functions[16]. Given optimal prices in importer and exporter's currencies, the choice between the two denomination strategies depends on the convexity of the latter profit function[17].

Recent years have seen the general equilibrium models in which exporting firms can choose price-setting currencies. These are Bacchetta and van Wincoop (2001), and Engel and Devereux (2001). Their common finding is that for exporters it is preferable to set prices in the currency of a country with lower monetary volatility. Again, these authors link exchange rate pass-through with the nominal rigidities. Pass-through of exchange rate is connected with the pricing of exports in a familiar way. As Devereux and Engel (2001) put it down, "A country that has highly volatile monetary policy will find that its import prices will be pre-

[16] For a simple case of linear demand functions and constant average cost Friberg (1996) shows that the profit function is concave in the exchange rate.

[17] Friberg (1998) extends this analysis to allow the strategic interdependencies between firms. In his model, a firm's denomination strategy depends on competitors' actions.

set in foreign currency, and as a result it will experience a high rate of pass-through from exchange rates to imported good prices".

Currency substitution

The themes of this paper are somewhat close to those analyzed in Loyo (2001). He considers the possibility of posting prices in so-called "imaginary money", disembodied units of account, which is linked to the means of payment ("real money") through parity managed by the state. In the face of possible cost shocks and nominal rigidities a firm can price in pure units of account to have the relative price of its product changed. If the parity between pure units of account and means of payment is predictable at average, some firms may decide to price in imaginary money depending on the extent that these firms are subject to shocks. Government, on the other hand, by manipulating the parity between the two moneys may adjust relative prices in order to minimize relative price misalignment. Under these circumstances, if parity and shocks are predictable at average, Loyo (2001) points out the possibility of self-organizing network of users of different units of account[18]. However, it is presumed that the parity between the two moneys is set to minimize the relative price misalignment. The paper concerns about the gains of having such an alternative to conventional unit of account as imaginary money. We are purposed to consider what is the effect of exchange rate on domestic prices, if denomination in multiple units of account is possible.

The paper by Loyo (2001) does not belong to currency substitution literature genre as such; the latter traditionally pays an exclusive attention to the domestic

[18] This author presents the case for such network for producers whose demand shocks are highly correlated with the price; pricing coordinately in a separate unit of account could help them minimize relative price misalignment in response to shocks.

currency displacement at medium of exchange and store of value roles of money[19]. In words of Giovannini and Turtelboom (1994),

> Little is known about the unit of account function of moneys, except for the fact that making calculations in relative prices using different units of measurement is always a very cumbersome task…We suspect that habit, both in its spatial (that is market thickness) and temporal dimensions, is an important factor determining the substitutability of unit of account services. The more people are used to operate in different currencies to settle transactions, the more these currencies' unit of account services will be substitutable. Similarly, the longer people have been used to operating in different currencies to settle transactions, the more these currencies' unit of account services will be substitutable.

Currency substitution studies implicitly presume that price setting in foreign currency is driven by the amount of foreign money in circulation and that price-setting currency and invoicing currency always coincide[20]. We are by no means going to demur to this statement, but these papers intend to study somewhat different phenomena. It is not decisive for our theorizing in what currency the actual payment is made, as soon as invoiced price is calculated at the recent exchange rate. The use of "notional units" in pricing illustrates this point[21]. However, we use this implicit assumption for estimation purposes.

Currency substitution studies point out that foreign money tends to replace domestic money in a unit of account capacity in high inflationary economies

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[19] By currency substitution, following Agenor and Khan (1992), we denote a situation in which foreign money substitutes for domestic money in its three traditional role. Definitions of currency substitution and its distinction from dollarization have always been tricky issues. There exist an overwhelming number of attempts to ultimately distinguish these concepts. The most broad definition of currency substitution, as Calvo and Vegh (1992), and Giovannini and Turtelboom (1994) notice is "a situation in which domestic money demand is influenced by foreign economic variables". McKinnon (1985) distinguish between direct currency substitution and indirect currency substitution. The former occurs when several currencies compete as a means of payment within one commodity domain. The latter is a form of capital mobility and refers to the situation, when investors switch between assets denominated indifferent currencies. In terms of Calvo and Vegh (1992), currency substitution is the use of several currencies as media of exchange; and dollarization is defined as the displacement of domestic money in its capacity of a unit of account and a store of value. From this viewpoint the current work falls into dollarization literature.

[20] Posting prices foreign currency may be facilitated by the absence of local liquidity. Camera and Winkler (2001) build a general equilibrium model with bilateral trade, where sellers choose currency in which to trade and the price (or prices) invoiced and find that there are equilibria where prices set in different currencies are identical.

[21] Practice of setting prices in "notional units" is discussed in the third chapter.

(Calvo and Vegh, 1992; Dean and Feige, 2002). Posting prices in foreign exchange, agents might opt by minimizing the number of necessary price adjustments and the amount of related menu cost and cost of loosing consumers who prefer to see prices stable (Zamouline, 2001).

Empirical treatment of currency substitution issues faces a fundamental difficulty. In most cases currency substitution is unobservable. Neither the amount of foreign cash in circulation nor proportion of prices set in foreign currency can be accurately measured.

The share of foreign currency in circulating cash can be the approximation for popularity of pricing in foreign exchange. As we are interested in evolution of this variable over time rather than in its levels, this approximation may be closer[22]. De Freitas (2000b), among others, notes that as soon as foreign currency denominated interest-bearing assets yield positive nominal interest, apart from risk considerations they dominate foreign cash. Hence, foreign cash is held mainly for transaction purposes[23].

It is not uncommon yet to measure currency substitution (understood as the displacement of domestic currency in means of payment capacity of money) with so-called dollarization ratios. The latter measure the ratio of foreign currency deposits to some broad monetary aggregate. The critique of such approach dates back to Cuddington (1983) and Thomas (1985). Among others, Moron (1997) argues that dollarization ratios measure the displacement of domestic currency denominated interest-bearing assets in a store of value capacity rather than in

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[22] The variable of interest is evolution of pricing in the foreign exchange over time rather than the proportion of output prices of which is posted in the foreign exchange, since we evaluate the correlation between currency substitution and pass-through. The size of the effect in this context is of second order importance.

[23] Feige et al. (2000) note that in some countries foreign banknotes may serve as a store of value. On the other hand, Moron (1997) and De Freitas (2000a) note that interest-bearing assets also have some degree of liquidity. De Freitas (2000a) reveals that foreign currency deposits have liquidity value and are thus incomparable to foreign bonds. This is apt for the case of Belarus, where foreign bonds are not available for the population, and the only foreign currency denominated interest-bearing assets are foreign currency deposits.

medium of exchange capacity. He notices that in general the share of liquidity services provided by the foreign exchange may not equal the weight of foreign currency denominated deposits. There could be dissimilarity between the behavior of dollarization ratios and proportion of foreign currency denominated assets in circulating media of exchange. A number of currency substitution studies model hysteresis in currency substitution, when temporary changes in forces that drive currency substitution (first of all, inflation rates) engender permanent changes in currency substitution (Guidotti and Rodriguez, 1991; Uribe, 1997; De Freitas, 2000a). In Guidotti and Rodriguez (1991) this happens because of non-zero transaction cost of adjusting holdings of currencies. Uribe (1997) presents the model where hysteresis is explained by network effects. Moron (1997) posits that hysteresis is exhibited by assets substitution rather than domestic currency displacement in a medium of exchange capacity. Thus, asset substitution measured by dollarization ratios, and the share of liquidity services delivered by foreign currency denominated assets may diverge.

The prolonged use of dollarization ratios may be facilitated by the absence of an integrated alternative. There were proposed several techniques to capture currency substitution, but none of them fit our case.

Feige et al. (2000), as earlier Kamin and Ericsson (1993), use the aggregated information from the files of Reports of International Transportation of Currency or Monetary Instruments to estimate the amount of dollars circulating in Croatia[24]. Because of the openness of the Belarusian border for Russians, however, the data collected from the Reports of International Transportation of

[24] The Currency and Foreign Transactions Act (1970) obliged a person or an institution that imports or exports currency crossing the USA border in amount exceeding $5,000, to submit a Report of International Transportation of Currency or Monetary Instruments. In 1980, the reporting threshold was raised to $10,000. Of course, currency imports in small amounts and illegal imports are not caught by these reports, which is a problem.

Currency or Monetary Instruments provide little information on the actual size of foreign currency imported to Belarus[25].

Feige et al. (2000) propose also so-called denomination displacement method. Since foreign currency is typically used for large transactions such as the purchases of real estate, cars, or other durables, in a country that experiences high degree of currency substitution domestic currency is demanded primarily for small transactions. Denomination structure in such a country will be unusually skewed away from higher denomination bills, provided that agents tend to economize on the number of bills used in a given transaction. The inspection of the denomination structure of Belarusian currency for the last decade, however, reveals that only small and occasionally mid-sized denomination notes were circulating[26]. This can be treated as a sign of high degree currency substitution in Belarus, but the variation in the denomination structure is too small to obtain consistent estimates for foreign cash held by the population[27].

The main lesson of pass-through literature is that the penetration of foreign currency denomination strategy is crucial for the degree of exchange rate pass-through. In the absence of price discrimination, exchange rate changes pass through into import (consumer) prices to the extent that appropriate basket comprises foreign currency denominated goods. The denomination of international trade literature stresses the role of price stickiness in creating dissimilarity of outcomes depending on price-setting currency. In the world of

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[25] Dean and Feige (2002) note that according to the aggregated data from Reports International Transportation of Currency or Monetary Instruments per capita holdings of the US dollars in Belarus were 0.8 in 1999, while results of surveys and informal interviews conducted by Federal Reserve and Treasury in 2000 estimate that average Belarussian holds 288 US dollars.

[26] In Feige et al (2000) definition, small denomination notes are those having face value in terms of US dollar values less than $10; mid-sized denomination notes have face value between $10 and $50.

[27] There were some attempts to estimate the foreign currency holdings based on creating analogies between the countries. The work by Doyle (2000) falls into this category. Another strand of empirical work base on ad hoc presumptions concerning domestic demand for liquidity services or money demand. What is left unexplained by the domestic currency holdings and other measured assets, is attributed to the foreign cash held. The works by Moron (1997) exemplifies this sort of research. Although intuitively appealing, such models are hardly transferable from one country to another, as Giovannini and Turtelboom (1992) note.

fully flexible prices an exporter does not bother in what currency units to invoice, as he can always adjust his prices. Price stickiness makes him treat denomination issues with caution, as profits may differ on the choices of a unit of account. Currency substitution literature emphasizes the difficulties in estimating the amount of transactions carried out in foreign currency (which can be closely related to popularity of posting prices in foreign exchange); as a rule, empirical strategy should seek indirect ways of obtaining these estimates.

Chapter 3

ECONOMIC ENVIRONMENT IN BELARUS

Currency substitution is observed in virtually all post-Soviet countries[28]. Its amplitude, however, is quite different across borders and is closely related to country-specific factors. The main task of this chapter is to overview the Belarusian backgrounds against which agents have to decide in what currency to post prices.

Foreign exchange

Belarus underwent several mutations of the exchange rate regime. The country inherited from the Soviet Union the system of multiple administratively determined exchange rates that were used in accounting of foreign trade operations[29]. Monetary policy was under control of the Central Bank of Russian Federation, since Russian roubles replaced Soviet currency in circulation[30]. On the 18th of March 1992 the National Bank of the Republic of Belarus (NBRB) announced the adoption of multiple administratively adjusted exchange rates under the direct control of the NBRB. Three rates were put in effect: the rate under which exporters were obliged to surrender their foreign exchange proceeds

[28] Currency substitution was subject to analysis in Estonia (Heimonen, 2001); Lithuania (Vetlov, 2001); Latvia (Sarajevs, 2000); Ukraine (Bondarenko, 2000); Russia (Goldberg and Karimov, 1997), and Kyrgyz Republic (Mongardini and Mueller, 2000).

[29] By January 1992, two official exchange rates were determined, while the parallel market exchange rate exceeded them by more than 12 times (Rusakevich, 2001).

[30] Gruzitskij (2002) overviews the movement of Belarus toward the issuance of the national currency in the early 1990s.

to the NBRB, and two other exchange rates used in accounting[31]. In 1993, the "unified" exchange rate was adopted; however, exporters still had to surrender their foreign exchange proceeds at less favorable rate (60% of the "unified" exchange rate)[32]. The year 1992 was marked by the first attempts of the NBRB to independently push in circulation notes denominated in roubles. These notes, issued by the NBRB, and Russian roubles circulated in parallel. The population put unequal credibility in these assets, and the "market" rate of exchange between the two was subject to some conjectural variations. The economy gradually went toward the appropriation of monetary policy solely by the NBRB. The Belarusian rouble became the only legal tender on the territory of Belarus in the second half of the year 1993[33]. This year is also remarkable in a different aspect: in March 16 Belarusian banks created the Interbank Currency Exchange (that later on was called the Interbank Currency and Stock Exchange).

During 1994 and the most of 1995 the official exchange rate of the NBRB was the one determined on the Moscow Interbank Currency Exchange. The domestic currency lost 94% of its initial value in terms of the US dollar during that period. As a result, on November 1995 currency exchange was tightened. The interbank exchange market was virtually closed, and the NBRB fixed official exchange rate at 11,500 roubles vis-a-vis the US dollar. Monetary aggregates targeting was announced; however, aggregates grew faster than targets, thus facilitating the loss of credibility (IMF, 2000). By the end of the year the exchange rate depreciated significantly. This gave rise to capital controls measures. The NBRB imposed 10% duty on the purchase of foreign exchange. Exporters were required again to

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[31] Years 1991-1993 are often classified as a period of premature system of multiple exchange rates. For description of the Belarusian economy, see e.g. links at the Internet host http://www.belarusian.com/links/index.htm#currency.

[32] Surrender requirement was abolished year and a half later; however, the abolishment turned to be only temporary.

[33] On May 18, 1994 the old Belarussian roubles were conversed at the rate 10:1 to new roubles. The conversion ultimately demarcated the introduction of an independent Belarusian unit of account.

surrender all of their foreign exchange proceeds. The initial surrender requirement was decreased later to 50%; and later on – to 30-40%[34]. The taxation of surrendered export receipts was fickle and might serve as a cost-additive item for exporters: in the second half of 1999 it was the case that surrendered receipts were accounted and taxed at the market exchange rate. However, some exporters were given certain privileges in what concerns the surrender requirement. In fact, this meant the heterogeneity of required foreign exchange proceeds across exporters. The effective (weighted average) rate of foreign exchange surrender was somewhat lower than the announced rate.

With the fixation of the official exchange rate to the US dollar Belarus embarked upon the regime of multiple exchange rates. The IMF (2002b) analysts point at the systematic multiple rates practice since January 1996, when foreign exchange as such was abolished for population, till September 2000. During the past 5 years, the difference between the official exchange rate and the parallel market exchange rate (see the figure 3-1) hurt Belarusian exporters who were enforced to sell a proportion of their receipts at the official rate. The deviation of the official exchange rate from the parallel market rate may imply the loss of credibility to the announced exchange rate policy and may incite the population to shield against unstable domestic currency by holding foreign denominating balances (IMF, 2000).

The figure 3-1 depicts these two exchange rates. Y axis is logscaled, because the amplitude of the rate fluctuations significantly increases over time.

Two periods of multiple exchange rates are clearly identified on the figure: one – in the time of incipience of Belarusian independence, another one – since 1996 till the year 2000. The latter is visibly featured with high spread between the rates – it was equal to 3 for some months.

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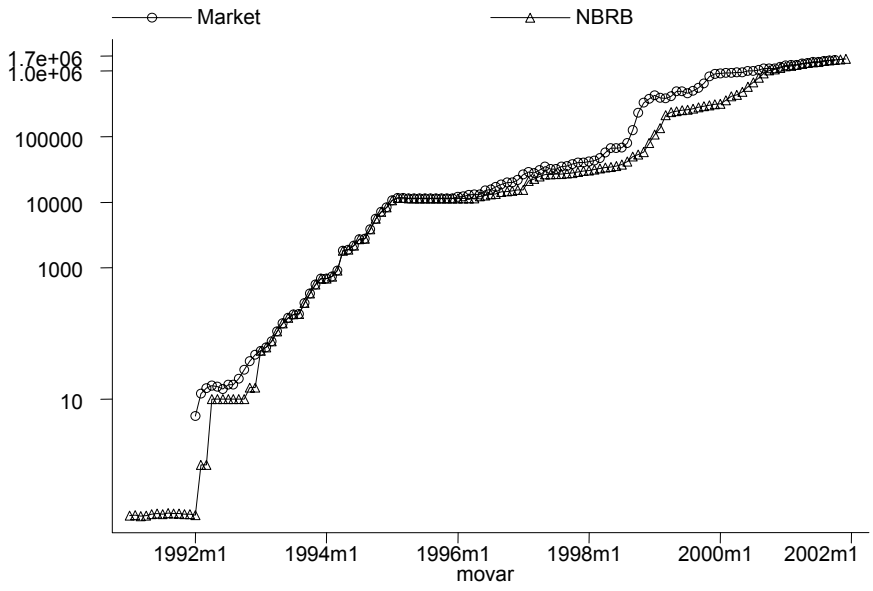
[34] Additional temporary surrender requirements were imposed on exporters from time to time. For instance, on July 20, 1998, 10% mandatory surrender requirement in the afternoon session of the Belarussian Currency Exchange was introduced until January 1, 1999 to cover energy bill in foreign exchange (IMF, 2000).

Figure 3-1. Official exchange rate and market (interbank) exchange rate in Belarus in 1992-2001, BRB/USD



Source: Institute for Privatization and Management

The foreign exchange rationing was further facilitated by currency crisis in 1998. Up until March 1998 the market value of the Belarusian rouble was reflected by the market rates determined at the Moscow Stock Exchange (Institute for Privatization and Management, 2002). In the beginning of 1998 the Belarusian rouble suffered an attack on the currency in this market, depreciating by 1/4 in less than two weeks. This engendered the great disparity between the officially announced exchange rate and the one at which currency was traded in the external markets. The NBRB, however, was not able to meet this divergence with foreign exchange interventions in the external markets. Its scanty foreign exchange reserves were never able to cover one month of imports, as is seen from the following table.

Table 3-1. Gross international reserves of the NBRB in 1998 – 2001 in terms of US dollars and months of imports

Gross international reserves of the NBRB:	**1998**	**1999**	**2000**	**2001**
- in millions of US dollars	*345*	*309*	*357*	*338*
- in months of imports	*0.5*	*0.6*	*0.5*	*0.7*

Source: International Monetary Fund

The Central Bank of Russian Federation decided to suspend the market for the Belarussian roubles in accord with the NBRB wishes (Institute for Privatization and Management, 2002)[35]. The policy response within Belarus was to cut the channels of Belarussian currency outflow from the country. The payments to non-residents on imported goods, as well as the payments on exported goods from non-residents, could not be legally invoiced in the Belarussian roubles[36].

Economists often blame the excessive money creation policy, pursued by the NBRB, for currency crises in 1995 and 1998[37]. In fact, the period of relatively free foreign exchange in 1994-1995 was featured with the decreasing rates of growth of money supply, which run contrary to Belarussian experience in 1991-1994 and November 1995-2001 (Rusakevich, 2001). The figure below represents the monthly rates of growth of monetary aggregate M2, devaluation rate of the market exchange rate (the discussion on what to consider the market exchange

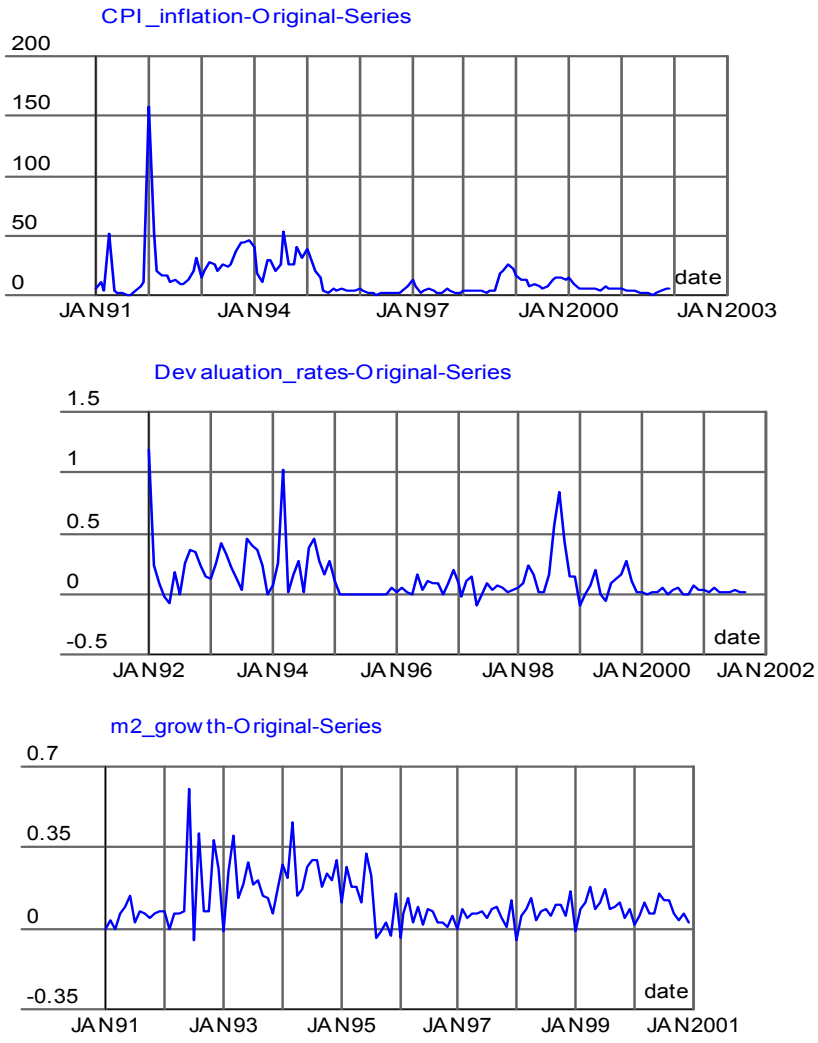
[35] The Moscow Interbank Currency Exchange resumed trading in the Belarusian roubles only in November 2001 (IMF, 2002b). For the description of 1998 currency crisis evolution, see http://www.uni.pt/activid/cetran/march_1998.htm.

[36] This decision was effective March 23, 1998. Effective March 26, 1998, payments to exporters from non-residents in the Belarussian roubles were again allowed, as well as payments by residents to non-residents with some exceptions. Effective October 23, 1998, imports could be paid in foreign exchange only (IMF, 1999).

[37] For example, see Rusakevich (2001), IMF (2002b), IMF (2002a).

rate for the case of Belarus is in the subsequent chapter), and the CPI inflation for the period.

Figure 3-2. Monthly CPI inflation rates, devaluation rates, and M2 growth rates in Belarus in 1991 (January) – 2001 (July).



Source: Institute for Privatization and Management

Rusakevich (2001) notes that cumulative (for 12 months) indices of exchange rate devaluation and inflation are close to similar indices for money supply growth. Being a small open economy with large import energy bill, increasingly denominated in hard currency, Belarus thus bears significant costs of pursuing soft monetary policy and exchange rate devaluation.

Recently the authorities endeavored to reverse the process of foreign exchange controls escalation. By the beginning of the year 1999, as the IMF (2000) reports, four exchange rates were in effect: (1) the auction rate at the Interbank Currency Exchange at which the official exchange rate was based and at which exporters surrendered their export receipts; (2) the supplementary market (set up in January 1998) where exporters might sell foreign exchange after fulfilling the surrender requirements; (3) the interbank market rate; (4) rate for individual cash transaction. Most transactions took place through the interbank market exchange rate. In 1999 there were two official exchange rates - the official noncash exchange rate and "recommended" cash exchange rate (IMF, 2000). The number of exchange rates in effect fluctuated until after the unification of the official exchange rate in September 2000. Since the unification, the difference between the daily auction and the interbank market rate was within a small margin. On the 1st of January 2000, the cash exchange rate market was liberalized, and exchange bureaus were allowed to set rates freely. All privileges concerning the surrender requirement were removed by November 2001. The IMF (2002a) analysts note: "While the surrender requirement must be conducted at the Belarus Currency and Stock Exchange, this does not give rise to a multiple currency practice, since it is the NBB's policy, through market participation, to maintain exchange rate deviations between market segments within a 2-percent margin. Consequently, no multiple currency practices remain."

Currency substitution in Belarus

After the unification of the exchange rate, the NBRB announced the policy of exchange rate targeting. The NBRB intends to keep the Belarusian rouble vis-a-vis Russian rouble within a 5 percent band around adjustable parity. In order to achieve this goal, the NBRB intervenes in the market when it is necessary. Exchange rate targeting presumably enhances central bank credibility and the transparency of pursued policy (IMF, 2001).

Adopting this exchange rate regime is a first step of pre-announced movement toward monetary union with Russia[38]. In turn, the Central Bank of Russia also intervenes to support the exchange rate.

Targeting the exchange rate vis-a-vis the Russian rouble, however, disagrees with the economic practice in the country. The role of the Russian rouble at Belarusian market is much lower than that of the US dollar. Even foreign trade of Belarus with Russian Federation is denominated mainly in the US dollars[39].

The US dollar dominates other currencies as a store of value. The lion proportion of deposits held in the domestic banks is denominated in the US dollars, as is seen on the figure[40].

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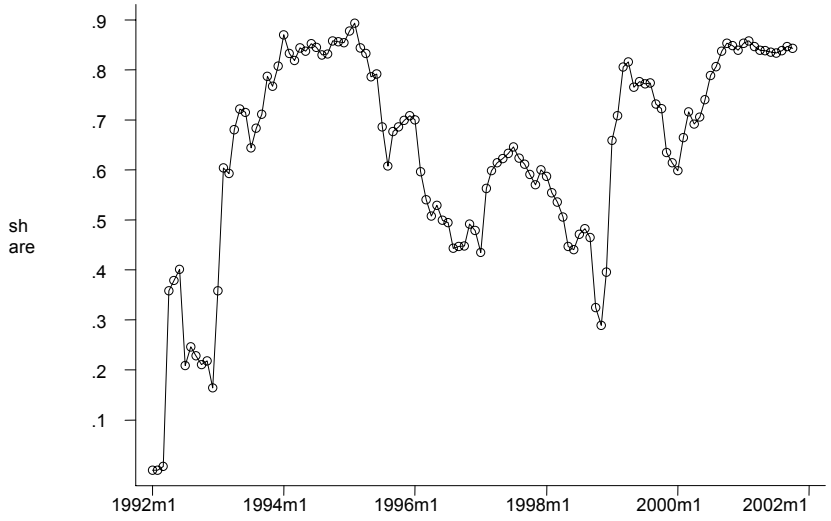
[38] The discourse on the possibility of common currency restoration began soon after the establishment of independent monetary policy in Belarus, in 1993. The economic integration with Russia is motivated both by economic and noneconomic conditions. For a discussion of economic union with Russia, see IMF (2002).

[39] E.g., in the year 2000 near 4% of Belarusian exports were invoiced in dollars, while only 10.1% - in Russian roubles; for 2001 the figures are similar - 45% and 14.9% respectively. Belarusian imports are also priced primarily in the US dollars: the proportions are 45% for 2000 and 47% for 2001; the Russian rouble served as a currency of invoice for 6.5% of imports in 2000, and for 11.9% of imports in 2001. Moreover, barter trade occupies somewhat larger share of Belarusian foreign trade than its proportion denominated in the Russian roubles. Barter prices are often related to the dollar exchange rate (Institute for Privatization and Management, 2002).

[40] It is remarkable how the proportion of foreign exchange denominated deposits in total deposits in the domestic banks vary depending on what exchange rate is used in calculations. As the most part of transactions is carried out in interbank exchange rate, the larger estimate is more reliable (IMF, 2002).

Figure 3-3. Proportion of foreign currency deposits in the total amount of domestically held deposits, 199-2001.



Source: Institute for Privatization and Management

The government actively stimulates the creation of foreign currency deposits. Domestic banks need to meet lower reserve requirement with foreign currency deposits than with deposits in Belarusian roubles[41]. Moreover, since 1998 the government has been providing additional guarantees to the depositors that invest the foreign currency. Presidential decree #4 obliged the government to secure the foreign currency deposits (principals as well as interest payments) held in 6 largest Belarusian banks. These measures were seen as the response to the Russian energy suppliers' claims for raising the ratio of settlements through the US dollars[42].

[41] By the year 2002, effective reserve requirement for foreign currency deposits was projected at 8.8%, while that for deposits in the Belarusian roubles was approximately 4 percentage points higher (IMF, 2002a).

[42] See e.g. http://chronicle.home.by/9804/9804160002.htm.

The population is also expected to hold large amount of cash in dollars under the mattress for transaction purposes. According to the NBRB estimates, the population foreign currency holdings count for 2 billion US dollars[43] (Rusakevich, 2001). In the times of tightening the foreign exchange the purchases of the US dollars were made through the mediation of black market dealers. Soon after the legalization of foreign exchange in 2000, the demand for the US dollars in exchange bureaus increased significantly[44].

Transacting in dollars is widespread in Belarus. It is a common practice for most market retail traders to accept US dollars as means of payment[45]. Probably the most striking example is setting wage targets by the government and the President in foreign currency terms[46]. Salaries in the private sector are often paid in dollars under the counter.

On the 25th of June 1996, the NBRB adopted the Instruct on posting prices and transacting in foreign currency[47]. The cases in which it is possible behind the trivia are: (1) duty-free trade; (2) insurance of residents of Belarus, departing abroad, and non-residents visiting the country; (3) tariffs on transportation across the border of Belarus. This listing was expanded by the homonymous instruct adopted by the NBRB on the 6th of January 1998. The latter document decreed

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[43] Dean and Feige (2002) project comparable figure of $288 per capita holdings.

[44] By 2000, there are approximately 1600 exchange bureaus in Belarus; daily transactions in the foreign exchange in bureaus count for near 1 million US dollars (Institute for Privatization and Management, 2002).

[45] The situation at the time of peak in currency substitution was similar to the Peruvian dollarization, described by Moron (1997): "The dollar traders at the streets where everywhere in Lima. At some point, you were able to pay even a taxi fare in dollars."

[46] Recently, the government intends to increase average wage in rouble terms to the amount equivalent of $100 per month; this added 1.4% of GDP to the wage bill in budgetary sector (IMF, 2001).

[47] "Instruct on the implementation of retail trade and services for the foreign currency in the territory of the Repuiblic of Belarus" #767 by the National Bank of the Republic of Belarus (Положение о порядке осуществления розничной торговли и оказания услуг гражданам за иностранную валюту на территории Республики Беларусь №767).

to post prices on gasoline at the filling stations in the foreign exchange, namely, US dollars. Also it allowed trading in dollars in the stores along the highways, and in so-called brand stores. In the December 2001 the NBRB decided to cut off the number of issued licenses.

Apart from quoting prices directly in dollars, Belarusian businesses employ pricing in so-called "notional units". Under this pricing strategy, all prices in the store are quoted in the artificial units of account. This unit of account, in turn, is "priced" in the Belarusian roubles. The "price" of one artificial unit is relatively easy to adjust without bearing significant menu cost. As a rule, the "price" of one notional unit is equal to the market exchange rate measured in the Belarusian roubles vis-a-vis one US dollar. Hence, "notional unit" pricing is often a form of circumventing frequent price adjustments by the same token as when pricing in the foreign currency units, but without resorting to the US dollar as an immediate money of account.

Currency substitution had risen at the date of the currency crisis of 1998; and the government considered further legal expansion of pricing and transacting in the US dollars. In January-April 2000 three Belarusian enterprises were experimentally allowed to set prices in the foreign currency. So far, however, this experiment has not resulted in legislative initiative.

Posting prices in the US dollars, apart from yielding proceeds in hard currency and possible advantages of unexpected gain (to be discussed in the subsequent chapter), allows adjust price schedule relatively easy. However, this is not always the case in Belarus, where the proportion of prices is administered.

Price controls

By the beginning of 1991 Belarus had made little progress in price liberalization comparing with the neighboring countries: 25% of consumer prices were

liberalized[48]. During the first months of 1992, the number of controlled prices decreased tremendously. The process resulted in an overwhelming inflation rate in 1992, which is clearly seen at the upper panel of the figure 3-2. Nevertheless, during the following three years the authorities continued to liberalize consumer and producer prices. By the end of this period, only utilities prices and a number of food items prices were left under government regulation. Later, in 1994 - the first half of 1996, a part of services prices was also liberalized. Some of the controlled services (energy and electricity for households and enterprises) used imported inputs in their production. Remunerated costs of such services were automatically indexed in parallel with devaluation rates and in accord with the fraction of imported inputs prices in the costs of production.

Presidential decree #345, signed in 1996, marked a deceleration in price liberalization development in Belarus. The decree froze the prices of bread, milk, and infant food till the end of the year. Housing and communal services cost were not allowed to exceed half household budget, the rest to be covered from the local budgets and by means of ad hoc price cuts. Local expertise of "socially important" goods prices was to be carried in order to make these good affordable.

The upward trend in price controls stamped the years 1997-2000 (Rakova, 2000). The direct controls over some prices were complemented by the adoption of price increase ceilings in 1997. Presidential decree # 584 imposed a 2% per month ceiling for price increase. Larger price increases were legally allowed only by a special permission from the Ministry of Economy[49]. However, monthly inflation ever increased this limit. Much of this was owing to the widespread

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[48] By the beginning of 1991, in Russia about 40% of consumer prices were liberalized; for the Central European countries the proportion was even higher (Rakova, 2000).

[49] In 1999-2000, indicative price increase ceilings were 4-5% per month. Larger price increase was not prohibited, but it had to be registered some months ahead in the Ministry that monitored an appropriate sector of the economy. New goods prices were also subject to registry (Rakova, 2001). In 2001, the authorities imposed two-digit (15-18%) indicative quarterly price increase ceilings instead. Price increase ceilings were removed in the 3rd quarter of 2001.

practice of creating dummy brands that allowed enterprises to set prices for their produce each month anew[50]. However, operative price adjustment was hindered by these regulations, and one could observe strong price rigidity with enterprises posting prices for a period in advance.

On the 10th of May 1999, the President signed the Law "On Pricing", previously in April adopted by the both Chambers of the Belarusian Parliament. The Law allowed for the following types of price controls in Belarus: (1) price fix; (2) price ceiling; (3) price increase indicative ceiling, and ceiling on mark-up; (4) price registration. According to the Law, The President of Belarus has the right to make a list of administered price items.

The goods, prices of which were and are under governmental control in Belarus, fall into the three categories: (1) prices of socially important goods; (2) prices of goods produced by enterprises that are considered to be monopolists; (3) prices of goods produced by "strategic" enterprises (IMF, 2002; Rakova, 2001). Some export and import prices were and are subject to control (salt, timber, fertilizer, flax).

The first category refers to the core foodstuffs (dairy products, meat products and poultry, bread), energy, and utilities. Mentioned foodstuffs' prices are not allowed to increase by more than administered increase ceilings.

Energy and utilities tariffs are either subject to discretionary change or indexed automatically (IMF, 2002b). Low cost recovery (defined as a proportion of the unit production costs that is reimbursed by the price) in key utilities and energy was and is one of the IMF claims against the Belarusian authorities[51]. Since 1999, the announced strategy of the government was to enhance the cost recovery of

[50] Oftentimes suppliers only modified the face names of their products and registered them as new ones.

[51] Costs of utilities and energy production are covered by the direct subsidies, special taxes on enterprises, and cross-subsidies. Cross-subsidizing means that enterprises pay an additional charge for their consumption of energy in order to compensate lower tariffs paid by the population (IMF, 2002a).

the energy and utilities tariffs by a way of tariff adjustments and automatic indexation tied to the industrial production index (IMF, 2002b)[52].

The monopolists listing includes, first, natural monopolies: oil refinery plants, transportation and communication suppliers, producers of medicines, whose prices are directly controlled; second, a number of enterprises monitored by the Antimonopolist Committee to exclude the malversation of their dominating positions. Over the years 1999-2001, transportation and communication tariffs rose relatively parallel to the CPI increase, but there were periods of significant real change in these tariffs, thus making suppliers' profitability time variant[53].

Strategic producers list (25 enterprises) includes the suppliers of alcoholic beverages, energy plants, and military suppliers. The government set prices for the products of these enterprises.

The IMF (2002) considers the underpricing of the aforementioned goods and services to be implicit subsidies to producers and/or consumers. Total amounts of subsidies as percentages of GDP in 1997-2000 are presented in the following table.

Table 3-2. Consumer and producer subsidies as percentages of GDP in 1997-2000

Subsidies in:	***1997***	***1998***	***1999***	***2000***
Transport and communication services	0.7	0.7	0.4	n/a
Housing and communal services	0.9	1	1.2	n/a
Energy and construction	0.3	0.4	0.3	0.2

Source: International Monetary Fund

Since 2000 the government made some important steps toward price liberalization. The list of controlled goods was reduced by 45 percent. The number of consumer goods and services subject to price controls was reduced

[52] By November 2001, household cost recovery in different utilities were between 11 and 35% (IMF, 2002a).

[53] For example, in January – September 1999, the local train tariffs were not changed, while CPI went up by 103%.

from a weighted 27-30 percent of the CPI basket at the beginning of 2001 to 20-22 percent by the end of November (IMF, 2002a). Price increase ceilings were lifted in 2001, as well as most of imports and exports price restrictions.

As we observe, the administrative regulation of prices during the recent years was intensive in Belarus. On the other hand, a proportion of prices was set in foreign exchange. Apart from tariffs that are automatically adjusted in accord with the exchange rate fluctuations, this means that prices of the goods that belong to two groups (controlled and uncontrolled commodities) change disproportionately. This hypothesis finds support in Kovalev (2001), who estimates that in Belarus administered prices are more volatile around the overall price level than prices that are set freely.

However, marginal price increase ceilings may present the case for widespread nominal rigidities. Calvo, Celasun, and Kumhof (2002) name three cases for nominal rigidities: (1) exogeneous arrival of price changing opportunities; (2) staggered contracts; (3) exogeneous shocks of adjusting prices. In the case of Belarus, the first case deserves special attention. An enterprise, bound by price controls, cannot respond promptly with price adjustment. Some businesses are able to circumvent this shortcoming by obtaining license for posting prices in the foreign exchange. Another strategy is to illicitly quote prices in the foreign exchange and hide some of the proceeds. Uncontrolled enterprises may opt by pricing in "notional units" or implicitly calculating prices in the US dollars. Finally, there are commodities that can be priced in the Belarusian roubles only, since the authorities closely monitor them. The economy wide composition of these price-setting strategies may affect the exchange rate pass-through as is described in the subsequent chapter.

Chapter 4

THEORETICAL FRAMEWORK

This section starts by exploring the rationale behind the single firm's choice of price-setting currency. Specifically, it studies the applicability of the main points of exports denomination literature for the case of domestic firm that chooses currency denomination. Taken the fraction of firms pricing in foreign currency for granted, it is then shown that unexpected exchange rate change can produce effect on the overall price level.

Individual firm's motivation to deviate from denominating in the home currency

As was mentioned in the second chapter, high inflation alone may cause firms to switch into pricing in foreign currency (Calvo and Vegh, 1992; Dean and Feige, 2002). Indeed, if changing a price is costly, high inflation may impose significant menu cost on a supplier. If devaluation rates follow inflation rates, then posting prices in hard foreign currency may be a shield against high menu cost (inevitable for a firm pricing in domestic currency) or loss in profits (plausible for a firm keeping constant prices in terms of the home devaluing currency). If the firm deters for some period from changing price in terms of domestic currency, price may deviate from momentary profit maximizing level. Foreign currency pricing allows supplier to change the price without paying much of menu cost or other cost associated with frequent price changes. If there is a cost of currency conversion, then firm compares the benefits discussed above with cost of conversion when deciding in what currency to invoice.

This chapter offers another plausible explanation for the observed phenomenon of setting prices in foreign currency units. Employing denomination of international trade-like simple model, we find that price rigidity in the currency of denomination can engender firm's deviation from pricing in the home currency[54]. The analysis is built on a set of assumptions that are standard for exports denomination literature, namely, floating and uncertain exchange rate, monopolistic profit maximization, and preset prices[55]. We already saw in the previous chapter that price rigidity assumption may be apt for the Belarusian case. Most transactions with foreign exchange in Belarus are carried at the parallel market exchange rate, which is definitely not known in advance.

Exchange rate in this section denotes the market price of a foreign currency unit in terms of domestic currency units. It should not necessarily be equal to any kind of officially determined exchange rate[56]. This provides the ground for employing the market rather than the official exchange rate in the estimation section.

Despite the disagreement among currency substitution theorists regarding the definition of the term "currency substitution", it is not rare to refer to the term when describing the replacement of domestic currency in any of the following capacities of money – medium of exchange and store of value – by its foreign counterpart. In an analogous way, we can label the displacement of the domestic money in its price-setting role as currency substitution. In this sense the current section explores the link from currency substitution into the correlation between

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[54] Inflation alone cannot serve as an adequate explanation for the presence of foreign currency denominating producers when prices are set only one period ahead. Depending on the difference between inflation rate and devaluation rate, all producers would denominate in one currency. Denomination of foreign trade-like approach reveals that each producer residual demand function and cost function, as well as their guesses at others strategies can influence the choice between the two currencies of denomination.

[55] These assumptions are typical both for partial equilibrium invoicing literature (see, e.g. Giovannini (1988); Ahtiala and Orgler (1995); Friberg (1996)) and (except for exchange rate uncertainty) for general equilibrium models by Devereux and Engel (2001); Bacchetta and van Wincoop (2001).

exchange rate and prices. The analysis begins with describing in the general form the rationale behind monopolist's choice of denomination strategy.

A monopolist faces a demand function q(p), where p is the price evaluated in the home currency, and a cost function c(q). The firm has to set price one period ahead, whether because of menu cost or any other reason. The price may be set in units of one of the two currencies, home (it can be "rouble") or foreign (it can be "dollar"). All costs are incurred in the home currency. The exchange rate e is the only source of uncertainty in the model. The exchange rate is measured in units of the home currency per unit of the foreign currency. The firm is maximizing its expected profits[57]. Following Devereux and Engel (2001), the firm can be presumed to maximize the expected present value of profits using the discount factor for its owners. The absence of an intertemporal aspect of the optimization problem allows reducing it to maximizing instantaneous profits each period separately by choosing the price and the denomination currency one period ahead.

If the firms decides to set price in the home currency ($p=p^{DCP}$), then the realized demand estimated in the home currency, and realized profits are known in advance. If the firm denominates price in the foreign currency ($p=p^{FCP}e$), then price in the home currency units, corresponding demand and realized profits are uncertain. Profits for the two cases in the home currency units are respectively[58].

$$\Pi^{DCP} = p^{DCP} q(p^{DCP}) - c(q(p^{DCP})) \qquad (4\text{-}1)$$

---

[56] Soller and Waller (1998) show that even under legal restrictions agents may opt by transacting in foreign currency.

[57] Risk neutrality, however, is not considered a necessary condition for denomination of international trade models results considering the choice of price-setting currency (Bacchetta and van Wincoop, 2001). We assume it here just for simplicity.

[58] DCP and FCP stand for "domestic currency pricing" and "foreign currency pricing" respectively.

$$\Pi^{FCP} = p^{FCP} eq(p^{FCP} e) - c(q(p^{FCP} e)) \tag{4-2}$$

The exchange rate changes pass through completely into prices preset in dollars. Hence, the firm does not know realized profit in advance, and it makes the decision on the base of expected exchange rate, E(e). To ensure against irregular functions that are only locally concave or convex, we follow Bacchetta and van Wincoop (2001) in focusing on uncertainty in the close neighborhood of E(e).

Maximization of profits in the case of DCP brings the following first order condition:

$$\frac{\partial \Pi^{DCP}}{\partial p^{DCP}} = q + p^{DCP} \frac{\partial q}{\partial p} - \frac{\partial c}{\partial q} \frac{\partial q}{\partial p} = 0 \tag{4-3}$$

which is equivalent to the familiar mark-up pricing rule for a monopolist:

$$\frac{1}{\varepsilon} = \frac{p - MC}{p} \tag{4-4}$$

where ε denotes the absolute value of price elasticity of demand.

Now let us turn to profit maximization first order condition in the case of FCP.

$$\begin{aligned} &\frac{\partial \Pi^{FCP}}{\partial p^{FCP}} = eq + p^{FCP} e^2 \frac{\partial q}{\partial p} - \frac{\partial c}{\partial q} \frac{\partial q}{\partial p} e = \\ &= e\left[q + \left(p^{FCP} e - \frac{\partial c}{\partial q} \right) \frac{\partial q}{\partial p} \right] = 0 \end{aligned} \tag{4-5}$$

We assume that the second order conditions of the concavity of both profit functions (4-1) and (4-2) with respect to prices hold.

Since for the FCP case $p=p^{FCP}e$, the equation (4-5), when expectations e=E(e) are substituted into it, simply replicates the mark-up pricing rule. However, this trivial finding is important in a sense that it shows that for the monopolist will not deliberately deter from the deterministic prices:

$$\hat{p}^{FCP} = \hat{p}^{DCP} / E(e) \tag{4-6}$$

where the hat symbols denote profit-maximizing prices. Hence, unlike an exporting firm, for a domestic firm that is free to choose the currency of denomination in an economy with one period ahead preset prices there is no room for optimal price discrimination[59]. The equation (4-6) also implies that expected profits of the monopolist will be the same no matter in what currency he invoices.

Unlike the profit function for the case of DCP, which is independent of the exchange rate, the profits under FCP are a function of exchange rate. We can now estimate how the profits of the monopolist change in exchange rate by deriving and estimating the first order derivatives of the profit function with respect to exchange rate in the optimal point where (4-5) holds.

$$\begin{aligned} \frac{\partial \Pi^{FCP}}{\partial e} &= p^{FCP}\left[\left(q + p\frac{\partial q}{\partial p}\right) - \frac{\partial c}{\partial q}\frac{\partial q}{\partial p}\right] = \\ &= p^{FCP}\left[q + \left(p - \frac{\partial c}{\partial q}\right)\frac{\partial q}{\partial p}\right] \end{aligned} \tag{4-7}$$

Estimated at profit-maximizing price, this derivative is essentially zero:

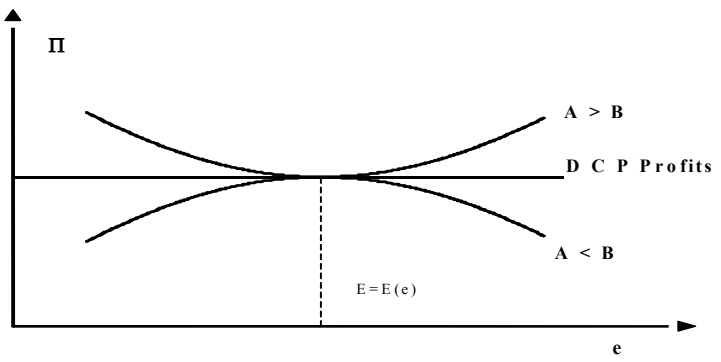
[59] Bergin and Feenstra (2001), for example, present the model in which monopolistic exporter discriminate between consumers in the two countries when denomination in the consumer currency for each market.

$$\left.\frac{\partial \Pi^{FCP}}{\partial e}\right|_{p^{FCP}=\hat{p}^{FCP}} = 0 \qquad (4\text{-}8)$$

This equation implies that for deterministic optimal prices, described by the equation (4-6), profit functions for DCP and FCP are tangent to each other in exchange rate – profits axes. The point of tangency (where both lines have horizontal slope) is e=E(e).

The choice between the two price-setting currencies is determined by the second derivative of FCP profit function with respect to exchange rate. The figure 4-1 illustrates that with convex (in exchange rate) FCP profit function an unexpected realization of exchange rate will result in higher profits to the monopolist denominating in foreign currency. Au contraire, when FCP profit function in exchange rate is concave, any deviation of exchange rate from expected level will result in lower profits of the monopolist pricing in foreign currency. Domestic currency pricing strategy provides given profits irrespective of exchange rate. The price (calculated ex post in the home currency units) set in foreign currency is exposed to exchange rate surprises; while the price set in the home currency is not.

Figure 4-1. Profits under denomination in domestic and foreign currencies as functions of the exchange rate



Given the convexity (concavity) of FCP profit function in exchange rate, FCP profits are at least (at most) as much as the DCP profits. Thus, FCP strategy necessarily dominates DCP strategy for the monopolist, if FCP profit function is convex in exchange rate.

There is no general case for convexity or concavity of FCP profit function in exchange rate. Appendix 1 illustrates the point of preceding discussion for a simple case of costless production. It is shown that the second order derivative of FCP profit function with respect to exchange rate equals:

$$\frac{\partial^2 \Pi^{FCP}}{\partial e^2} = (p^{FCP})^2 \left[3\frac{\partial q}{\partial p} + p^{FCP} e \frac{\partial^2 q}{\partial p^2} \right] \qquad (4\text{-}9)$$

Let us denote $A \equiv p^{FCP} e \frac{\partial^2 q}{\partial p^2}$ and $B \equiv -3\frac{\partial q}{\partial p}$. Under some regularity conditions, namely

$$\frac{\partial q}{\partial p} < 0;\ \frac{\partial^2 q}{\partial p^2} > 0 \qquad (4\text{-}10) - (4\text{-}11)$$

the second-order derivative of the FCP profit function with respect to the exchange rate is determined by two effects that have polar signs. Convexity of the FCP profit function in exchange rate, and the denomination the monopolist will chooses, is determined by which of these two effects dominates. The figure 3-1 represents both cases. When A>B, FCP profit function is convex, and any exchange rate surprise is profitable; and vice versa. The choices of the denomination currency and optimal prices as well are not affected by the change in exchange rate risk, understood as the standard deviation of exchange rate

around its expected level. Increasing or decreasing riskiness does not alter the relative convexity of FCP profit function comparing to DCP profit function[60].

These results are comparable to those that have been obtained in the export denomination literature, e.g. in Friberg (1996). In the export denomination studies, when prices are posted in the exporter's currency, the convexity of profit function in exchange rate is proved to be the sufficient condition for exporter's currency denomination being the dominant strategy[61].

Interaction between firms

However, the simple approach presented above overlooks the strategic interaction between firms. That is the point of Bacchetta and van Wincoop (2001) criticism toward the "old-style" partial equilibrium models of exports denomination[62]. Solution of a general model where firm's pricing decision depends upon prices set by other firms is hardly interpretable. For our purpose a simple model with linear (in relative price) demand function and constant average cost is appropriate.

The demand function of each firm is given by

$$q(p, P) = \alpha - \beta p + \gamma P \qquad (4\text{-}12)$$

where P is the overall price index that is defined as simple average of prices in terms of the home currency set by all the firms in the economy. Without the loss

[60] Bacchetta and van Wincoop (2001) make the similar observation regarding the influence of the exchange rate risk on exporter's prices and denomination. However, variability of profits under FCP pricing is altered when the exchange rate risk is changed.

[61] E.g. Bacchetta and van Wincoop (2001). The crucial difference from our settings is that both profit functions are exposed to the exchange rate uncertainty in the exporter's denomination problem, and both are increasing functions in exchange rate.

[62] However, Friberg (1996 and 1998); Ahtiala and Orgler (1995) make explicit assumptions on how residual demand that a single firm faces is related to overall price level.

of generality, we can presume firms symmetric in all respects but denomination issues. That is, if the fraction n∈[0,1] of all firms sets prices in the home currency in equilibrium

$$P = n\hat{p}^{DCP} + (1-n)\hat{p}^{FCP}e \tag{4-13}$$

The cost function is

$$c(q) = wq \tag{4-14}$$

A single firm is presumed not to influence price level. The general principal that determines in what currency a firm is invoicing, is close to that in the general model described above: if FCP profit function in exchange rate is relatively more convex, a firm will price in the foreign currency, and vice versa. The difference is that now both FCP and DCP profit functions are positively sloped where e=E(e). The complete solution of the model is presented in the Appendix 2. The main results of the model are:

$$\left.\frac{\partial^2 \Pi^{DCP}}{\partial e^2}\right|_{p^{DCP}=\tilde{p}^{DCP}} = 0 \tag{4-15}$$

$$\left.\frac{\partial^2 \Pi^{FCP}}{\partial e^2}\right|_{p^{FCP}=\tilde{p}^{FCP}} = 2\tilde{p}^{FCP^2}\left[\gamma(1-n)-\beta\right] \tag{4-16}$$

If (for given γ and β) (1-n) is large enough, then the whole second order derivative is positive, FCP profit function is convex in exchange rate, and strategy of pricing in the foreign currency necessarily dominates. The large number of competitors pricing in one of the two currencies may be a sufficient reason for a firm to imitate.

There is a clear intuition behind the equation (4-16). The large number of firms denominating differently from a given firm implies that under exchange rate surprise consumers can easily switch between firms. The firm therefore has strong incentives to switch into opposite pricing strategy.

There could be other driving forces of FCP in the economy. Friberg (1996), for example, mentions that imported inputs can provide an incentive to price in the importer's currency. In this case the cost function directly depends on exchange rate. The rationale behind the choice of price-setting currency is essentially the same.

It is also worth mentioning that the firm is not always free in determining the price denomination. The lion portion of commodity space may necessarily be priced in the home currency because of the government regulations. On the aggregate level we could assume a la De Freitas (2000b) that the proportion of goods that can be priced in foreign currency has upper boundary. The analysis above is applicable only to the cases when the firm can choose the denomination of the price[63]. Moreover, government regulations regarding the currency of invoice can have some network effect that reduces the attractiveness of FCP strategy for the firms, as is demonstrated by our model with interaction. Nevertheless, FCP is observed in some countries including Belarus. Thus, our analysis is not of pure theoretical interest.

Price level and exchange rate

We now turn into the examination of the overall price level exposure to exchange rate surprises assuming some given denomination strategy for each firm. The equation (4-13) is crucial for further estimation. It shows that when a part of

[63] E.g., it is possible to consider the possibility of illegal pricing in foreign currency, when there is a trade-off between the relative advantage of pricing in the foreign currency, and the probability of being caught and punished.

prices is set in foreign currency, and prices are pre-set, the overall price level is exposed to exchange rate changes.

Since all prices are predetermined, the equation (4-13) could be rewritten as follows:

$$P = n\hat{p}^{DCP} + (1-n)\hat{p}^{FCP}\left[(e - E(e)) + E(e)\right] \tag{4-17}$$

Now, applying the deterministic prices relationship (4-6) we can finally write the equation for the overall price index as

$$P = \hat{p}^{DCP} + (1-n)\hat{p}^{FCP}\left[e - E(e)\right] \tag{4-18}$$

As an alternative to the use of simple average overall price index, we could use geometric price index

$$P = (p^{FCP}e)^{1-n}(p^{DCP})^{n} \tag{4-19}$$

employed in Devereux and Engel (2000), and Devereux and Engel (2001); weighted average price index, or the power additive price index

$$P = \left(\sum_i w_i p_i^{1-\mu}\right)^{\frac{1}{1-\mu}} \tag{4-20}$$

employed in Bacchetta and van Wincoop (2001). But the main message remains robust to the choice between these specifications.

The gist of the relation modeled by the equation (4-18) can be described as follows. Exchange rate surprises e-E(e) may produce a positive effect on the overall price level in the economy where fraction of prices is preset in foreign currency. Moreover, the size of this effect increases in fraction of dollar prices in the economy. This fraction seems the natural measure of the degree of currency substitution in a unit of account capacity of money. Thus we can articulate this result in the following way: exchange rate surprises positively influence overall price level in the economy, and this influence increases in the degree of currency substitution in a unit of account capacity. These findings depend only on the assumptions concerning pre-set prices and uncertain exchange rate. The specific

form of the overall price index does not matter as soon as it is an increasing function of each commodity price.

An equation like (4-18) can be tested. As it will be seen in the following section, such testing calls for the use of nonlinear models.

In this chapter we first modelled the choice of denomination made by individual monopolistic producer. It was shown that the choice of currency, in which price is set, does not influence the equilibrium price in terms of domestic currency, when there are no exchange rate surprises and prices are pre-set one period ahead. However, non-zero exchange rate surprise fully passes through into the price denominated in foreign currency. Apart from demand and cost functions' properties, it was shown that the network effects may influence the denomination strategy of an individual firm. Finally, it was shown that under currency substitution in a unit of account capacity of money, with pre-set prices and exchange rate uncertainty, the surprise changes in the price of one unit of foreign currency has positive effect on the overall domestic price level. The size of this effect depends on the degree of currency substitution, that is, on popularity of posting prices in foreign currency.

Chapter 5

ESTIMATION AND RESULTS

Estimation strategy and econometric methodology

For several reasons it is impossible to simply regress price level on exchange rate. First, stationarity is an important issue for dynamic estimation, while exchange rate and price indices are clearly not stationary. Second, as it was already noted in the third chapter, Belarusian economy is featured with intensive money creation. Although in an economy with underdeveloped financial sector the monetary transmission mechanism may be not transparent, for such high values of monetary aggregates growth rates it is reasonable to expect that both exchange rate and price level be highly influenced by money supply. Hence the results of regressing price level on exchange rate are worthless. An alternative could be simultaneous estimation of the system of equations describing the behavior of the three variables. In fact, however, this implies three simultaneous equations estimation, as we cannot wittingly reject the influence of each of the three variables (exchange rate, price level, money supply) on the other two. However, estimation of the three simultaneous equations system with dynamic structure is an overwhelmingly complicated task. Moreover, the results would not be easily interpretable and would be sensitive to the choice of model specification. It is desirable to formulate a single equation model.

Another point to count for is the distinction between an anticipated exchange rate change and exchange rate surprise. For a simple price level described by the equations (4-13) and (4-17)-(4-18) anticipated exchange rate change fully corresponds to price level change. On the other hand, exchange rate surprise

passes through into the price level only to the extent that prices are posted in the foreign exchange. The presence of difference between the degree of pass-through of anticipated exchange rate changes and of exchange rate surprises is in general independent from the specific form of the overall price level. Pass-through is usually estimated not distinguishing between the two. However, using deviation of exchange rate from (an unobserved) equilibrium level would make the results more reliable.

For these reasons the estimation of the static model, describing exchange rate effect on the price level, utilizes the approach pioneered by Giovannini (1988). He uses detrended and deseasonalized prices and exchange rate to study the degree of pass-through. This is relevant for Belarus, where monetary variables are linked to agricultural seeding and harvesting campaigns financed heavily through directed credits (Rusakevich, 2001). Moreover, the presence of seasonals leads to the undesired autocorrelation in residuals (Greene, 2000, p.788).

Monetary aggregates strongly influence long-term values of price level and exchange rate measured by their trend values. The importance of monetary aggregate deviation from its equilibrium value as a factor influencing both exchange rate and price level short-run deviations is far less obvious. We can model the relationship by single equation with or without deviation of a monetary aggregate as a regressor, and check for multicollinearity in the former case. The main disadvantage of employing deseasonalized and detrended variables instead of the levels is that information used disables the model estimate long-term relation between the exchange rate and prices, which is likely to occur. Notwithstanding, the long-term exchange rate surprise is zero as soon as there are no systematic errors in expectations formation process.

Giovannini (1988) determines the trends of the appropriate variables by regressing them on time variable and time variable squared. In this research

(commensurably with the importance of expectations issue) more sophisticated approach is chosen.

Thus, the estimation strategy is as follows. First, we deseasonalize and detrend the series using the TRAMO/SEATS algorithm discussed later. Second, variables that are obtained by subtracting trends and seasonal components from the initial values are checked for stationarity by power of the augmented Dickey-Fuller test and Phillips-Perron test. Third, we estimate the simple static (that is, with time constant parameters) equation of exchange rate effect on price level for three price indices: consumer price index (CPI), producer price index (PPI), and agrifood price index (AFPI). The time spans for these three series are different. It is important to note, however, that we extract subsample of detrended and deseasonalized exchange rates from the same full-length sample of the detrended and deseasonalized exchange rate no matter for what time span the appropriate price index is available. This is so to achieve congruence with respect to sample in Bontemps and Mizon (2001) sense[64].

After implementing estimation of the static equation, we check it for structural stability with the battery of tests (the Chow breakpoint test, CUSUM and CUSUMQ tests, Wald test for structural stability with unequal variance). Then we estimate the time-varying parameter alternative model of exchange rate effect on price level. Obtained time-varying coefficients, describing this effect, are then checked for correlation and Spearman rank correlation with the proxies for currency substitution.

This section briefly describes the intuition behind the econometric methods applied. Detailed formal treatment is behind the scope of this research, but appropriate references are provided.

TRAMO/SEATS seasonal adjustment

TRAMO/SEATS is a seasonal adjustment method promoted by the Eurostat and the European Central Bank[65]. It belongs to the class of ARIMA-model based time series decomposition approaches; however, TRAMO/SEATS program is different in that adjustment of the series depends on the statistical properties of the series, while other ARIMA-model based filters are empirical in the sense that adjustment does not depend on the properties of analyzed series (Dosse and Planas, 1996). It is common for this class of models to consider time series in general case as being made up of three unobserved components: (1) the trend-cycle components that correspond to the general direction reflected in the data; (2) seasonal components that include time-related effects; (3) irregular components that combine effects that cannot be predicted by the ARIMA model. It is assumed that these three components are not correlated. ARIMA-model based approaches implicitly assume that, each component is of the ARIMA type, using moving average filters can help clean up the series of any of the three components.

TRAMO ("Time Series Regression with ARIMA noise, Missing Observations and Outliers" allows estimate regression model with nonstationary ARIMA errors. The program performs interpolation of errors and outliers prediction. SEATS ("Signal Extraction in ARIMA time Series"), following ARIMA-model-based method, decomposes series into unobserved components (Kaiser and Maraval, 2000).

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[64] Bontemps and Mizon (2001) note that congruent model is data coherent (consistent with the observed data sample).

[65] Chapter 4 in Bloem, Dippelsman and Maehle (2001) discusses the main principles of seasonal adjustment and different families of seasonal adjustment programs. Detailed analysis of seasonal adjustment issues is carried out by Planas (1997); Kaiser and Maraval (2000) discuss ARIMA-model based algorithms of seasonal adjustment; Dosse and Planas (1996) compare empirical and model-based seasonal adjustment methods.

TRAMO/SEATS preludes the estimation of errors and their decomposition with the identification of the series, that is, determination of orders of the stationarity and autocorrelation. Hence, the procedure is series sensitive.

In general, the decomposition of monthly series y in the ARIMA type-model is performed by estimating the following regression:

$$y_t = \mu^{(t)} + \sum_{j=1}^{11} \beta_j^{(t)} d_{jt} + \alpha_t \qquad (5\text{-}1)$$

where d denote seasonal dummies, μ is trend component, and α is irregular component that cannot be explained by the model. All the coefficients adapt slowly over time; they are estimated iteratively in state space time-varying parameter framework that will be discussed later. Hence, the trend component is evolving over time, making this sort of models applicable for analyzing expectations.

Decomposed series is subject to diagnostic tests. The most important ones are out-of-sample forecast and residuals normality tests.

Fully automatic TRAMO/SEATS seasonal adjustment procedure is performed by several statistical packages[66].

Unit root tests

This paper utilizes two tests for stationarity: the ADF (augmented Dickey-Fuller) test and Phillips-Perron test. To check series y for unit root by virtue of the ADF test, one should estimate the following equation (linear trend and/or constant term can be excluded) and checks whether the coefficient in front of lagged value of y is one.

$$\Delta y_t = \alpha + \beta t + \lambda y_{t-1} + \sum_{t=1}^{p} d_t \Delta y_{t-1} + u_t \qquad (5\text{-}2)$$

The Phillips-Perron test, instead of adding lagged differences to the list of regressors, adjusts threshold values of the statistic to incorporate possible error autocorrelation[67].

Tests for parameter constancy

The idea behind the Chow breakpoint test is to estimate the equation separately for different subsamples and compare if estimated coefficients in these estimations differ significantly[68]. This is implemented by comparing the sum of squares obtained in the single equation estimation, with sum of squares obtained when each subsample is estimated separately.

The CUSUM test and the CUSUMQ (CUSUM of squares) tests belong to the recursive estimation family tests. Recursive least squares estimate the equation in a repeated manner using expanding rolling sample defined below. Initially, equation is estimated for a number of observation equal the number of coefficients in the regression so that estimation if deterministic. Then the residuals for larger subsamples are estimated using the coefficients obtained in the first estimation. The CUSUM test plots cumulative residuals of this estimation and tests if they are within allowed band. The CUSUMQ test performes procedure, similar to the described above, with respect to cumulative squared residuals of the recursive estimation.

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[66] In the current research the seasonal adjustment was implemented in DEMETRA.

[67] Phillips and Perron (1988), Perron (1990), Dickey and Fuller (1981) consider different versions of unit root tests.

[68] For a formal description of the Chow test and other tests for structural break mentioned in this section see e.g. Greene (2000, pp.287-297) or help files for EVIEWS 3.1.

For these tests to be reliable, residuals should be independently normally distributed. To count for possible unequal variances in two subsamples, we employ Wald test for structural break with unequal variance. Like Chow test, it is based on comparison of coefficients values for two different subsamples, but Wald test weights difference in estimated coefficients by variance differential.

Rolling regression

Under detected parameter instability, static model estimation is no more reliable. Several techniques can be implemented to incorporate presumed time variance in the structure of the model. We focus on two techniques – rolling regression estimation, and state space modeling with time-varying parameters[69].

Rolling regression estimation can be implemented for moving sample or for expanding sample. In the former case a model is estimated for a subsample of a given size (called "regression window"), started from the first observation. Then it is re-estimated after dropping the oldest observation and adding the new one. The estimation proceeds till all the period is encountered. The regression window is usually 25, 50, or 100 observations. In the case of rolling regression with the expanding sample instead of substituting the new observation for the first one, the new observation is added to the subsample, and it is re-estimated then. The coefficient values are attributed to the last observation in each subsample, which is rather arbitrary. Another weakness of this method is the arbitrariness of the regression window chosen. Rolling regression is useful in confirming parameter instability and in detecting the general trends in coefficients over time, however, more precise analysis requires specifying the evolution of parameters, which is done in time-varying parameter estimation.

[69] Darvas (2001) performs rolling regression estimation to illustrate time instability of the pass-through relationship for the sample of the EU candidate countries. There are examples of rolling regression utilization in different fields of research – see e.g. De Koning and Straetmans (1997); Chiang (1988).

Time-varying parameter estimation

Time-varying parameter model is a version of a general state-space model which treats estimated variable as being dependent not only on a set of regressors, but also on possibly unobserved state variables[70].

The general representation of the state-space model with one variable of interest and stochastically varying coefficients consists of the two equations – one describing the behavior of the state variables, and the other describing the dynamics of the variable of interest given the state variable values. The first equation is called state (or transition) equation; the second one – observation (or measurement) equation.

In the case of univariate time-varying parameter model, conventional representation of these two equations system is:

$$\begin{cases} b_{s,t} = b_{s,t-1} + \varepsilon_t \\ y_t = a + \sum_{h=1}^{k} b_{h,t} \cdot x_h + u_t \end{cases} \qquad \text{(5-3)-(5-4)}$$

In this case the s-th of k regressors effect on variable y is time varying. The coefficient, describing its effect, is presumed to follow random walk.
Alternatively, it may be allowed to deviate around mean value.
State-space models like (5-3)-(5-4) are estimated using the Kalman filter algorithm. Given starting values of the state coefficient estimated by the OLS, it recursively updates each period's coefficient conditional on past information so that to maximize the likelihood function until the convergence is reached.

[70] Hamilton (1994, pp. 372-408) provides a comprehensive description of the Kalman filter, state-space models, and time-varying parameter models.

Spearman rank correlation

In view of possible discrepancy in the proxies for popularity of pricing in the foreign exchange, we employ both conventional correlation coefficient and Spearman rank correlation. It is based on the presumption that yet the proxied variable may not be measured with accuracy, but the orderings of its values are preserved in proxies. Spearman correlation coefficient uses rank orders of variables instead of their actual values.

Another issue of great importance besides estimation techniques employed is the data. It was noted in the second chapter, that empirical treatment of currency substitution related phenomena suffer from the unobservability of currency substitution as such. Hence it is necessary to find an appropriate proxy for currency substitution, in our case – for popularity of pricing in dollars.

Proxying for popularity of posting prices in the US dollars

There are no data on the extent of pricing in foreign currency in Belarus. We have to proxy the proportion of foreign cash transactions and proxy the popularity of pricing in the US dollar by these "first order" proxies.

As was noted in the second chapter, computationally appealing denomination displacement method of evaluating foreign cash in circulation in Belarus is not reliable. Instead this paper utilizes two other approaches to estimating currency substitution. First, data on foreign exchange proceeds of Belarusian enterprises allow us to proxy the displacement of the Belarusian rouble in a unit of account capacity by the proportion of foreign exchange proceeds in total revenues of Belarusian enterprises. Foreign exchange proceeds include both exporters' repatriated revenues in hard currency and domestic firms' proceeds in foreign currency. Unfortunately, this data do not count for households' foreign exchange holdings. Their fraction in the total cash can be different. Enterprises can hide

some foreign exchange revenues in order not to avoid obligatory surrender of a part of them. Hence, this proxy is not perfect. However, data on foreign exchange proceeds are the only available piece of information directly measuring foreign cash transactions in Belarus. Herefrom we denote this proxy CS.

Second, we employ conventional dollarization ratio as a proxy. The disadvantages of this method were discussed in the second chapter. Since it measures proportion of foreign currency deposits in total deposits rather than the proportion of foreign cash transactions, and it does not count for foreign deposits abroad, this proxy can be inaccurate. In our case, however, the latter bias can be negligible. In IMF(2000) foreign currency deposits in domestic banks are considered to be reliable estimator of the degree of currency substitution for the case of Belarus: "The incentive for capital flight – and hence the need to cover foreign currency deposits abroad – is large in countries that do not allow residents to maintain foreign currency deposits. In the case of Belarus, the authorities not only permit bank accounts in foreign currency but have been implementing policies that minimize the outflow of capital".

Both proxies can be biased in some respects. Applying both of them provides an advantage of complexity; together these proxies can bring into focus more than any one gauge apart.

Data and measurement issues

All the series analyzed in this research is obtained from the Institute for Privatization and Management database. The data employed are monthly time series.

Cumulative price indices (CPI, PPI, and AFPI) series have different time span. For CPI and PPI, monthly data is available for a period from January 1992 till December 2001. For AFPI, the time span is January 1995 – December 2001. CPI

uses weights from the previous year's Household Expenditure Survey, while PPI and AFPI are based on Laspeyres corrected index formula with the weights corresponding to the structure of production in 1993[71].

The market exchange rate compile Moscow Interbank Currency Exchange rates of Belarusian rouble per US dollar for the period January 1992 – February 1998, and parallel interbank market in Belarus for the period March 1998 – December 2001[72].

The dollarization ratio (DR) was calculated on the base of monetary aggregates that are reported in the NBRB report each month. The system of equations below presents the structure of monetary aggregates. In addition to conventional aggregates M0-M3, it includes aggregate M4, which accounts for foreign exchange element of domestic broad money.

M0=Domestic cash in circulation

M1=M0+Domestic currency demand deposits

M2=M1+Domestic currency time deposits

M3=M2+Other Domestic currency deposits

M4=M3+Foreign currency deposits

However, foreign currency deposits in rouble terms reported by the NBRB are calculated at the official exchange rate, while most transactions in the country is carried out through the parallel market exchange rate (IMF, 2000). Therefore, we reestimate foreign currency deposits in rouble terms in accord to the market

[71] Parsley (1995) criticizes the use of aggregate price indices for estimation of the pass-through because of changes in commodity basket. As is seen, the use of CPI is subject to this sort of criticism, while PPI and AFPI are robust to it.

exchange rate. In the subsequent analysis, "dollarization ratio" denotes the ratio of foreign currency deposits in rouble terms to broad money M2, that is

$$DR = \frac{M4 - M3}{M2} \tag{5-5}$$

The monthly data on monetary aggregates M3 and M4 are available for January 1992 – November 2001. M2 monthly statistics are available for January 1992 – January 2001.

The second proxy for currency substitution (CS) was calculated as the proportion of foreign currency proceeds of Belarusian enterprises (evaluated in roubles) to nominal GDP. The monthly data for both series are available for the time span January 1996 – April 2001. It is collected by the NBRB in order to trace foreign exchange surrender requirement realization.

Deseasonaling and detrending series

Appendix 3 presents formal results of the seasonal adjustment stage. We present the results only for series that prove to be statistically significant in subsequent estimation. Results of seasonal adjustment are quite satisfactory. TRAMO/SEATS reveal significant seasonality in all series. Prior to decomposition, all variables were subject to log transformation. Adjustment diagnostics is based mainly on the two criteria: (1) Ljung-Box statistic for autocorrelation in residuals; (2) Forecast error over last year statistic that measures the forecasting power of the performed adjustment. The austerity of claims for adjustment with respect to these two criteria depends on the goals pursued by researcher. Since we do not intent to use the series for forecasting, but instead are interested in looking at the relationship between errors that are

[72] All the data were revised to reflect the removal of three zeros from the currency on the 1st of January, 2000.

unexplained by seasonal factors and/or trend, we can relax the requirements to some extent.

Adjustment diagnostics revealed some autocorrelation in adjusted CPI and PPI series, but Ljung-Box statistics are close enough to preselected 95% significance critical values. M1 series exceeds preselected upper bound for forecast error over last year, but slightly. Seasonal adjustment of remaining series reveals no serious diagnostic problems.

Unit root tests and static estimation

Both augmented Dickey-Fuller and Phillips-Perron test document the absence of unit root in deseasonalized and detrended series. The table (5-1) reports the tests p-values and the numbers of lags, which are chosen by minimizing the Akaike information criterion within general-to-specific procedure for the ADF test[73]. For Phillips-Perron test, the number of lags is not reported, since the p-values are zeroes for a wide range of number of lags.

Table 5-1. Unit root tests for adjusted series

Series[74]	Augmented Dickey-Fuller test		Phillips-Perron test
	p-value	nr. of lags	p-value
Exchange rate (market)	0	2	0
CPI	0.002	4	0
PPI	0.001	3	0
AFPI	0.01	5	0
M1	0	4	0

[73] The table presents the results with the inclusion of a constant term and trend. The unit root hypothesis is also rejected if these terms are excluded.

[74] In the remainder of this chapter variable name denote deseasonalized and detrended series, without special notification.

Stationarity of the series allows for estimation of the static equation. Simple fixed parameter model to be estimated is:

$$P_t = \alpha + \sum_{h=0}^{k} \beta_h e_{t-h} + \sum_{g=0}^{l} \delta_g M_{t-g} + \varepsilon_t \tag{5-6}$$

where P denotes price index, M – monetary aggregate, e – nominal exchange rate[75].

The choice on monetary aggregates and the number of lags (k and l respectively) to encounter is made on the basis of model performance and diagnostics. Specifically, for each price index we checked each monetary aggregate in turn to determine which enhances the coefficient of determination most of all. Ultimate version of the fixed coefficient model should survive general tests for correctness of specification. Since we expect the coefficients in front of nominal exchange rates to be unstable, the number of lagged terms is chosen without taking coefficient stability issues into consideration. Moreover, as De Koening and Straetmans (1997) notice, time-varying structure of the model implies heteroscedastic disturbances. Therefore, we rule out homoscedasticity considerations either. Darvas (2001), solving the similar task, chooses the number of lags so that: (1) likelihood ratio test reports no abundant variables and lagged values; (2) the Ljung-Box (Portmanteau) test reports the absence of the autocorrelation in residuals. We follow these recommendations and show that, while the fixed-coefficient models survive these tests, they fail to satisfy the aforementioned tests for structural stability. Since monetary aggregates are included in the list of regressors, it is also worth checking for multicollinearity

[75] Different other variables (real exchange rate misalignment, standard deviation of the past inflation, average nominal wage) suggested by vast pass-through literature have not prove to be significant in our case.

between regressors. Test for multicollinearity is performed by means of variance inflation factor (VIF)[76].

Using general-to-specific procedure, we obtain the fixed coefficient models for the three price indices. The t-statistics are given in the parentheses.

Table 5-2. OLS fixed coefficient models of the exchange rate pass-through

Regressors (lag)	CPI	Regressors (lag)	PPI	Regressors (lag)	AFPI
Constant	-0.001301 (-0.34)	Constant	-0.000611 (-0.16)	Constant	0.000567 (0.3)
Exchange rate	0.149980 (3.66)	Exchange rate	0.176165 (4.11)	Exchange rate	0.030623 (1.6)
Exchange rate(1)	0.140214 (3.42)	Exchange rate(1)	0.120582 (2.83)	Exchange rate(1)	0.013165 (0.68)
Exchange rate(2)	0.048065 (1.17)	Exchange rate(2)	0.182837 (4.3)		
Exchange rate(3)	0.105906 (2.57)	M1(1)	0.212474 (2.62)		
Exchange rate(4)	0.115906 (2.8)	M1(2)	0.134673 (1.65)		
M1(1)	0.154318 (1.94)	M1(3)	0.185725 (2.29)		
M1(2)	0.127917 (1.63)				
Adjusted R^2	0.33		0.34		0.01
DW	1.95		1.65		2.01
Average VIF	1.03		1.02		1

LR test by construction rejects the hypothesis that any of the variable listed in the table is redundant. This is not the case, however, for AFPI fixed coefficient model, where p-value of the test for redundancy of both exchange rate terms is 20.62%. The model presented in the table for AFPI, is the model that fits best; however, AFPI deviations does not virtually depend on either exchange rate surprises or money supply. Hence the power of the model for this index is low.

The results of the fixed coefficient pass-through estimation are the following. Immediate pass-through (measured as the coefficient in front of present

[76] For the formal description of the tests applied to fixed coefficient model see e.g. Greene (2001) or help files

exchange rate deviation) of exchange rate surprises into CPI and PPI deviations from expected values are nearly equal. Cumulative effect of a unit exchange rate surprise on these series is also near similar (0.560071 for the CPI, and 0.479584 for the PPI); however, the model suggest that the exchange rate surprise have a long-lasting effect on CPI rather than on PPI. From the standard pass-through studies viewpoint, this is not surprising that some lagged exchange rate surprises produces more effect on price level deviation than more current exchange rate surprises. Under price stickiness in domestic currency, exporters need time to adjust their prices in accord to past exchange rate fluctuations. As for Agrifood Price Index, the model suggests that the exchange rate surprises pass-through into AFPI deviations is, first, negligible (coefficients are slight), and, second, does not contribute significantly to the index deviations. A very plausible explanation is the large proportion of controlled goods in agrifood basket. Nevertheless, we proceed with dynamic estimation of AFPI model to consider if so far observed zero pass-through is consistent with the dynamic representation.

Estimation output is presented in Appendix 4. OLS estimates satisfy the claims for fixed coefficient estimation described above apart from the case of AFPI. It is worthy noting that VIFs in all three regressions suggest the absence of multicollinearity. Hence, the deviations of a monetary aggregate M1 are unlikely correlated with the exchange rate surprises.

The Durbin-Watson and the Ljung-Box statistics do not reveal significant autocorrelation in residuals of the three equations.

To substantiate single equation modelling, we check for Granger causality between price indices and exchange rates (all – in terms of deviations). The table

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of EVIEWS 3.1. For description of the variance inflation factor test see e.g. help files for STATA 7.0.

5-3 present the results of this testing. The test incorporates 5 lags of each variable.

Table 5-3. Pairwise Granger causality test for price indices and exchange rate

Null Hypothesis:	Obs	F-Statistic	Probability
XRATE does not Granger Cause CPI	115	5.23436	0.00025
CPI does not Granger Cause XRATE		1.67474	0.14719
XRATE does not Granger Cause PPI	115	4.67760	0.00068
PPI does not Granger Cause XRATE		1.77335	0.12476
XRATE does not Granger Cause AFPI	79	0.85912	0.51318
AFPI does not Granger Cause XRATE		4.63044	0.00107

The pattern of AFPI is again different from those of CPI and PPI. For the former the Granger causality test does not support single equation modelling, while for the latter two indices the results are promising.

To finalize the diagnostics of the fixed coefficient pass-through models, we check them for coefficient stability. The results of the CUSUM, CUSUMQ, Chow breakpoint and Wald tests with unequal variance are presented in Appendix 5. Presumed breakpoint for the Chow and Wald tests is chosen deliberately. It is the February 1998, featured with the rise of currency substitution in Belarus and the adoption of the NBRB Instruct that expanded the list of goods that could be priced in the foreign exchange. These tests unambiguously suggest that fixed coefficient models of the CPI and PPI are not stable. Even through the CUSUM tests provide some support for coefficient stability in these models, the Wald tests, the Chow breakpoint tests, and the CUSUMQ tests strongly support time-variability hypothesis. The evidence from the Wald test is especially valuable, since it is the general test in that it does not rely on homoscedasticity of errors. It is striking that this test is the averse to the coefficient stability to the highest extent. Hence, there is the necessity to consider dynamic models.

Rolling regression model estimation

In the estimation of the rolling regression we use the structure of the static model and let coefficients evolve over time. For rolling regression estimation, regression window of 25 observations was chosen because of the relatively short time span of the observed series. Appendix 6 contains the standard error bar charts of immediate and last month's pass-through coefficients for the three indices. Each chart represents appropriate estimated pass-through coefficient value with two standard error bands. As before, we calculate cumulative pass-through coefficients by summing up coefficients in front of all exchange rate surprise terms.

Pass-through coefficients variability is identified clearly by rolling regression estimates[77]. Results suggest that exchange rate surprises pass through to price level deviations in most cases.

The table 5-4 presents the distribution of all pass-through coefficients. They are divided into four categories: significant positive, insignificant positive, negative insignificant and negative significant. We label coefficient as positive significant, if its lower two standard error limit exceeds zero.

By the same token, coefficient is named negative significant, if its upper two standard error limit is below zero. Since coefficients' means and standard error evolve over time, there is no general method to determine standard error of cumulative pass-through coefficients. Hence, only mean values are reported for them.

The first column of the table names price index, for which the exchange rate surprise pass-through coefficient is presented in the appropriate row. It also

[77] We do not present the rolling regression coefficients for M1 terms in the Appendix. Although they show some variability, in general they are much more stable than pass-through coefficients.

designates the number of lags for exchange rate surprise term. Immediate pass-through denotes coefficient in front of no-lagged exchange rate surprise tem.

Table 5-4. Distribution of pass-through coefficients in rolling regression models

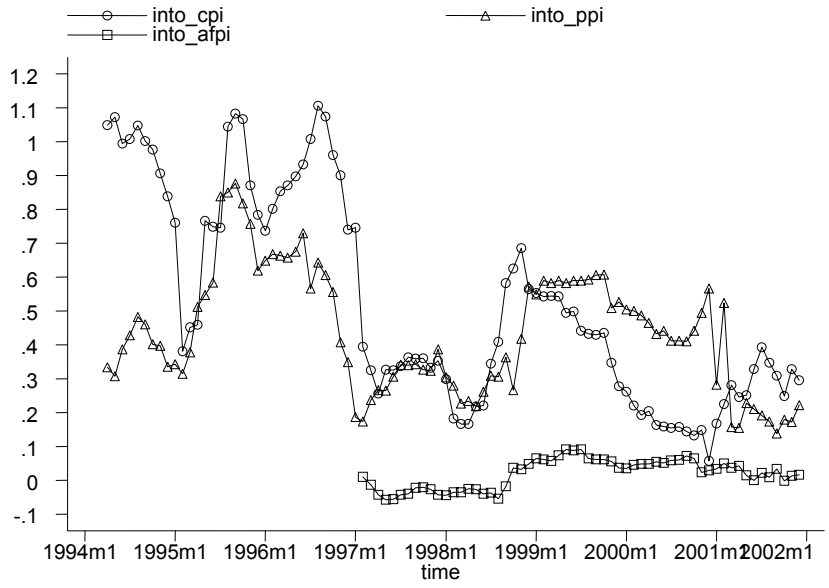
	Positive		Negative	
	Significant	**Insignificant**	**Insignificant**	**Significant**
CPI – Immediate pass-through	40.2%	44.5%	16.3%	0%
CPI – 1 lag	45%	55%	0%	0%
CPI – 2 lags	14%	59.8%	26.2%	0%
CPI – 3 lags	17.8%	82.8%	0%	0%
CPI – 4 lags	14%	64.5%	21.5%	0%
CPI – Cumulative pass-through	***100%***		***0%***	
PPI – Immediate pass-through	43%	52.6%	4.4%	0%
PPI – 1 lag	21.5%	71%	7.5%	0%
PPI – 2 lags	34.4%	65.6%	0%	0%
PPI – Cumulative pass-through	***100%***		***100%***	
AFPI – Immediate pass-through	12.1%	56%	31.9%	0%
AFPI – 1 lag	10.6%	50%	39.4%	0%
AFPI– Cumulative pass-through	***68.2%***		***31.8%***	

No negative significant pass-through coefficients are observed. Moreover, the best part of pass-through coefficients is positive; thus being in accordance with the pass-through theories. Both currency crises – in 1995 and in 1998 – are marked with positive significant pass-through coefficients, as well as second half of 1997 and 1999 (the years, in which the NBRB adopted instructs on pricing and transacting in the foreign exchange).

We can again observe the different paths of exchange rate surprises pass-through for CPI and PPI deviations, on the one hand, and for AFPI deviations, on the other hand. Apart from the year 2000, evaluated pass-through coefficients into AFPI deviations are much less than those into the two other indices deviations.

Furthermore, negative pass-through coefficients are found only in the case of AFPI. The figure 5-1 plots the cumulative pass-through coefficients for all three indices.

Figure 5-1. Cumulative pass-through coefficients in rolling regression models for CPI, PPI, and AFPI



We can observe that all three cumulative pass-through coefficients follow rather similar pattern of motion over time. However, pass-through coefficient for AFPI fluctuates near zero, while the other two are much larger. Apart from the period sup to January 1995 and some months in 2000 pass-through into PPI and CPI deviations moved in one direction, but pass-through into CPI deviation is more volatile.

Agrifood Price Index stands alone in that only a small part of its deviations is explained by exchange rate pass-through. The ranges, means, and standard

deviations of R squared of rolling regressions models of pass-through for all three indices are in the table 5-5.

Table 5-5. Range, mean and standard deviation of the R squared in rolling regression models

	R^2 range	Mean R^2	Standard deviation of R^2
CPI rolling regression model	*[0.2484-0.7516]*	*0.5190*	*0.1200*
PPI rolling regression model	*[0.1417-0.6602]*	*0.4084*	*0.1569*
AFPI rolling regression model	*[0.00001-0.1597]*	*0.0634*	*0.0430*

As in the static model, exchange rate surprises seem to produce negligible effect on deviations of AFPI. Therefore, we do not observe significant pass-through into agrifood prices deviations in the rolling regression model.

Unlike R squared, average values of other diagnostic statistics over the set of rolling regressions are not very informative. Researchers usually use rolling regression estimation as a prelude for time-varying parameter model and do not set up diagnostic tests (Harvas, 2001; De Koning and Straetmans, 1997). Since we already apply diagnostic tests to the fixed coefficient model of the same structure as each regression included in the set of rolling regressions, we can expect results be similar[78].

We are interested to measure how pass-through is related to currency substitution in a sense defined above. To gauge this, we employ correlation coefficients and Spearman rank correlation coefficients. The table 5-6 presents these coefficients for two proxies of the popularity of posting prices in foreign exchange and three price indices. We include in the table coefficients for correlation between lagged proxies and current price indices; and between lagged price indices and current

[78] Tests on several regressions from the entire set follow this expectation.

proxies' values. This is done in order to evaluate whether the observed correlation can be spurious. Since lagged values of currency substitution proxies are still related to current price indices, while lagged price indices are less correlated with current proxies for currency substitution, we expect that the correlation is not spurious[79].

Table 5-6. Correlation coefficients and Spearman rank correlation coefficients between proxies for currency substitution and pass-through coefficients estimated by rolling regression[80]

1. CORRELATION COEFFICIENTS						
	Cumulative pass-through into CPI	Cumulative pass-through into PPI	Cumulative pass-through into AFPI	Lagged cumulative pass-through into CPI	Lagged cumulative pass-through into PPI	Lagged cumulative pass-through into AFPI
CS	0.2509	0.4360	0.6202	0.0895	0.1156	0.5564
DR	0.2662	0.3199	0.7835	0.0334	0.0760	0.7348
Last month's CS	0.1728	0.3209	0.6363	-	-	-
Last month's DR	0.2710	0.3811	0.7854	-	-	-
2. SPEARMAN RANK CORRELATION COEFFICIENTS						
CS	0.2975	0.2310	0.6558	0.0701	0.0725	0.6061
DR	0.4526	0.1560	0.7453	0.0233	-0.0380	0.7157
Last month's CS	0.2272	0.1761	0.6745	-	-	-
Last month's DR	0.4672	0.1701	0.7832	-	-	-

The correlation coefficients suggest that pass-through of the exchange rate surprises is facilitated by currency substitution. It is worth noting the different paths of relationship between exchange rate surprise and price index deviation for Consumer Price Index and Producer Price Index. What concerns the former,

[79] For a discussion on spurious correlation, see e.g. Johnston and DiNardo (1997, p.10) or the seminal paper by Yule (1926).

[80] CPI, PPI, and AFPI are deseasonalized and detrended.

correlation coefficients are less than Spearman correlation coefficients with both proxies for currency substitution. Ordinal ranks of currency substitution proxies and pass-through into CPI are then related to each other closer than the levels of these variables. With PPI, the situation is opposite.

In both cases, however, the correlation coefficients present evidence that pass-through is positively associated with currency substitution. This association persists if we use lagged proxy for currency substitution. Lagged pass-through, on the contrary, is not associated with currency substitution. This finding is general for both correlation coefficient and Spearman correlation coefficient; and for both CPI and PPI.

Agrifood Price Index correlation with currency substitution proxies is the highest across all price indices. It is insensitive to the replacement of current proxy with lagged proxy value or current pass-through with lagged pass-through value. Hence, we cannot reject the possibility of spurious correlation in this case. Since the contribution of the exchange rate surprises to the explanation of AFPI deviations is low, the results of Table 5-6 are not instructive for that index.

Rolling regression models results might be dependent on the size of regression window. Thus, to further estimate the relation between currency substitution and the exchange rate surprises with more precision, we embark on time-varying parameter estimation.

Time-varying parameter estimation

Ideally, for our purposes time-varying estimation should be implemented for the following system:

$$\begin{cases} P_t = \alpha + \sum_{h=0}^{k} \beta_{h,t} e_{t-h} + \sum_{g=0}^{l} \delta_g M_{t-g} + \varepsilon_t \\ \beta_{h,t} = m + \phi_h CSP_{t-h} + \nu_t, \ h = \overline{0,k} \end{cases} \quad \text{(5-7)-(5-8)}$$

where, as in (5-6), P is a price level, M – monetary aggregate M1, and e – exchange rate (all – detrended and deseasonalized). CSP denotes currency substitution proxy (CS of DR).

At each time period, pass-through coefficients' values would include systematic component explained by currency substitution, and random component.

Yet, relatively short time span renders variance of large number of estimated coefficients very high. Moreover, only three processes for state equation are computationally available: random walk, random walk with drift, and AR(1) process.

We opt by the following strategy: initially observation equation (5-7) is restricted to one M1 term and one exchange rate surprise term (k and l equal to 0 for all indices). System of transition equations (5-8) is replaced by single random walk transition equation:

$$\beta_{t+1} = \beta_t + \nu_t \quad \text{(5-9)}$$

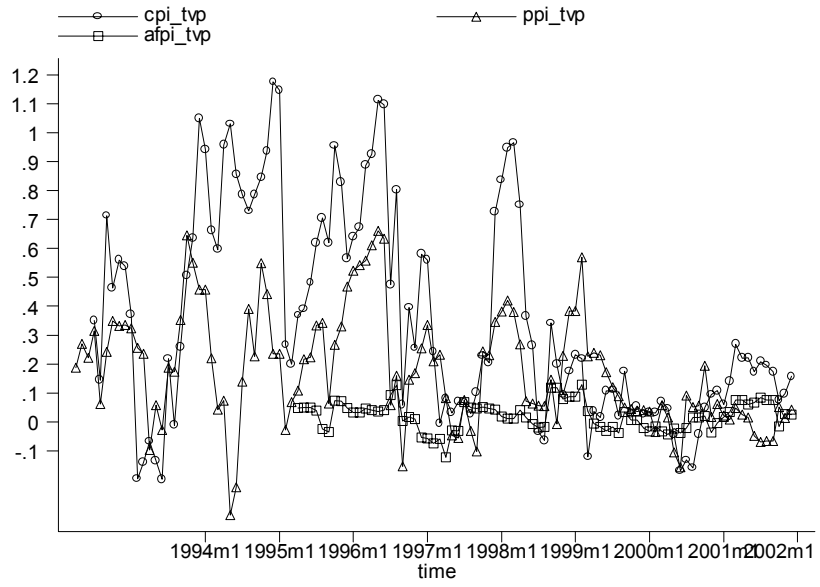
The motivation behind random walk specification for transition equation is that we consider exchange rate surprise shocks on price level. These shocks are likely to be persistent as in general there are no reasons why price level should reverse to some mean level after a shock.

Initial model is then improved on the case-by-case basis by adding and/or subtracting terms. The criterion is the log-likelihood function. In our case only CPI model is improved by adding a new term – lagged exchange rate surprise term is likelihood maximizing. AFPI model, on the contrary, enhances likelihood

function value when lagged exchange rate surprise term is excluded from the list of regressors. PPI model maximizes likelihood in its initial form.

Estimation output, as well as the distribution tables for the time-varying pass-through coefficients is presented in Appendix 7. The figure 5-2 below depicts the evolution of cumulative pass-through coefficients for three price indices.

Figure 5-2. Pass-through coefficients of the time-varying parameter model for CPI, PPI, AFPI



Significant disparity between the patterns of pass-through of different indices is observed. First, cumulative exchange rate surprises pass-through into CPI deviation is much larger than into the two other indices. Second, pass-through into Agrifood Price Index is, like in rolling regression and fixed parameter models, negligible. The explanatory power of the time-varying model is the highest for CPI, and the lowest for AFPI. Most individual pass-through coefficients are positive albeit insignificant. This confirms the analogous finding of the rolling regression models. Finally, exchange rate surprise effect on

Consumer Price Index is propagated over at least two periods, unlike the other two indices where it is clustered within single period. It is remarkable that even immediate pass-through into CPI alone is more than either of the two other indices pass-through coefficients.

The time-varying coefficient model diagnostics requires testing the assumption about the normality of residuals. The table 5-6 contains Jarque-Bera statistics on residual series of model estimated.

Table 5-7. Diagnostics of time-varying parameter models of pass-through

	TVP model of pass-through into **CPI**	TVP model of pass-through into **PPI**	TVP model of pass-through into **AFPI**
Log-likelihood function	167.2223	175.6744	201.2364
Jarque-Bera (J-B) statistic	4.54352	6.84676	1.78871
p-value of J-B	0.10313	0.03260	0.40887

Combined with the Durbin-Watson statistics calculated for the smoothed residuals, the Jarque-Bera statistics values suggest that time-varying estimation results are satisfactory. Relatively low predictive power of the model is the matter of controversy. We could add more terms to the observation equation and obtain significantly higher predictive power. However, this would lessen likelihood function value and render the estimation results less reliable. Adding more state space variables allows explaining dependent coefficient's variability by fluctuations in unobserved state variables, but this variability does not follow prescribed random walk process and it is not grounded on the theory. Thus, it should be treated with caution[81].

[81] For instance, in the AFPI model R squared could be increased to 93% by adding time-variant lagged M1 term. The price of this "improvement" is the loss of 50 point in likelihood function, and the inflation of

Next we look at the relationship between pass-through and currency substitution. The analysis is performed in a similar manner to that for rolling regression results. The table 5-8 presents correlation coefficients and Spearman rank correlation coefficients similar to those of table 5-6.

Table 5-8. Correlation coefficients and Spearman rank correlation coefficients between proxies for currency substitution and pass-through coefficients estimated by time-varying parameter model[82]

1. CORRELATION COEFFICIENTS						
	Pass-through into CPI (cumulative)	Pass-through into PPI	Pass-through into AFPI	Lagged pass-through into CPI (cumulative)	Lagged pass-through into PPI	Lagged pass-through into AFPI
CS	0.4022	0.1556	0.1106	0.1721	0.0879	0.1726
DR	0.4788	0.1025	0.0943	0.1957	0.0401	0.1222
Last month's CS	0.4079	0.1212	0.0356	-	-	-
Last month's DR	0.5012	0.1760	-0.0040	-	-	-
2. SPEARMAN RANK CORRELATION COEFFICIENTS						
CS	0.4427	0.1724	0.0848	0.1634	0.0800	0.1506
DR	0.2732	0.1899	0.1178	0.1647	0.0223	0.1101
Last month's CS	0.5394	0.1986	0.0068	-	-	-
Last month's DR	0.2878	0.3020	0.0011	-	-	-

It is observed that pass-through is quite close associated with currency substitution proxies. Correlation coefficients are not symmetric. While lagged currency substitution proxies are still associated with pass-through, lagged values of pass-through do not seem to contribute to currency substitution volatility.

time-varying pass-through standard errors: two standard error band of the modified model includes 1 and –1.

[82] CPI, PPI, and AFPI are deseasonalized and detrended.

Like in rolling regression model, pass-through into Consumer Price Index is best explained by currency substitution. Not to run the parallel, Spearman correlation coefficients for PPI model-based pass-through coefficients are more than correlation coefficients. Yet in both cases currency substitution seems to facilitate exchange rate surprises pass-through.

Agrifood Price Index deviations for time-varying parameter model do not closely follow currency substitution proxies. It is not possible to notice the presence of currency substitution effect on pass-through into AFPI, since lagged values of AFPI deviations are correlated with currency substitution proxies by more than lagged proxies with AFPI deviations. Hence, currency substitution driven exchange rate surprise transmission into agrifood price level increase is dubious. For the other two indices, on the contrary, we can expect that currency substitution eases exchange rate surprise pass-through.

Results and implications

Although the large part of pass-through coefficients estimated in this research are insignificant, the basic evidence is that positive pass-through of exchange rate surprises into price indices' (probably apart Agrifood Price Index) deviations from their "equilibrium" values is observed in Belarus. The absence of negative cumulative pass-through indices is supportive with respect to this statement. The second basic evidence with strong implications is that patterns of exchange rate surprises pass-through into price indices are different between the three indices used.

Consumer Price Index (at least in deviations) is most of all three indices vulnerable to unanticipated exchange rate fluctuations. The effect of a given exchange rate surprise on CPI is large (in comparison with PPI and AFPI) and relatively prolonged. This result was obtained for all three estimations: fixed

coefficient estimation, rolling regression, and time-varying parameter estimation. Hence, this finding is robust and does not strongly depend on specification.

Producer Price Index is subject to significant immediate exchange rate driven deviations. Again, this result is robust. Adding more lags of exchange rate in all specifications worsened estimation performance. Hence, long-lasting effect of exchange rate surprise on PPI (at least in deviations) does not find support in the data. The number of fitted lagged terms of exchange rate surprises for CPI models was more than for PPI models. The difference is not large, but it is systematic.

We cannot argue that Agrifood Price Index is dependent upon exchange rate . In all evaluations, AFPI models were not capable to explain any conspicuous amount of index deviations without distorting diagnostic performance of the model. Pass-through coefficients estimated for AFPI are always less than those for the two other indices.

Heterogeneity of pass-through patterns across price indices can imply serious consequences for economy. Recently, Belarus announced exchange rate targeting and price liberalization (IMF, 2002a). We observe that indices response to a given exchange rate change is allogeneous both in magnitude and continuance. Setting nominal exchange rate as an anchor and giving up some portion of price controls thus may engender the relative price shock between commodity groups. Large portion of agrifood commodities is controlled, and we observe relatively high and long-lasting pass-through into consumer prices. If exchange rate targeting is credible, and plans for price liberation are fulfilled, then, we can expect food price increase in terms if other consumer goods, as well as in terms of investment goods.

Such permutation in "real exchange rate" between prices of commodity groups can lead to output losses in one commodity groups (foodstuff in our case) and output gains in another one (investment goods and consumer goods apart from food items) during transition period, as Calvo, Celasun, and Kumhof (2002) postulate.

Exchange rate fluctuations are often associated with relative price shifts between tradables and nontradables, as the former group is exposed to exchange rate, while the latter is presumably not (Arratibel, Rodriguez-Palenzuela, and Thimann, 2002). Cuddington and Liang (1999) document volatility of relative price among two categories of tradables. In the extreme cases, this can be tracted as the argument for fixed exchange rate regime. Our estimation, however, is not helpful in this respect. We can only expect relative price changes.

This research provides some support to the hypothesis that currency substitution positively influences pass-through of exchange rate surprises. All appropriate correlations and Spearman rank correlation coefficients are positive. Furthermore, lagged currency substitution is still strongly associated with pass-through coefficients, while lagged pass-through association with currency substitution is not that high. These findings, of course, are not self-evident, as we had to proxy currency substitution in a unit of account capacity. Should we have precise data on popularity of pricing in the US dollars, only then the results would be fully reliable.

However, results are suggestive. The hypothesis that pass-through is positively related to currency substitution has implication in inflation inertia studies. Economies with low inflation steady-state rates are usually featured with much higher volatility in exchange rates (Devereux, Engel, 2002). As was noted above, pricing in foreign currency exposes price in terms of the home currency units to exchange rate fluctuations. In the presence of nominal rigidities, even credible

disinflation program can fail, if pass-through is positively related to currency substitution. As firms cannot continuously update their pricing rules, exchange rate fluctuations are transmitted to firms' prices, and inflation persistence is generated even if stabilization program is credible.

Chapter 6

CONCLUSIONS

Many developing and emerging market economies exhibit higher pass-through coefficients than more advanced countries. Current literature suggests different explanations for this observed phenomenon. Taylor (2000) hypothesize that what matters for high degree of exchange rate pass-through is inflationary environment. Devereux and Engel (2000, 2001) posit that emerging market economies are featured with unstable and incredible monetary policy. Hence, most part of foreign trade of these countries is denominated in hard foreign currency. As a result, large part of tradable goods prices is exposed to exchange rate fluctuations.

This research studies adjacent hypothesis: instead of seeking the sources of exchange rate pass-through in international trade related issues, we proposed to look at similar domestic sources that can contribute to exchange rate transmission into price level. Such manifestation of currency substitution as denomination of a portion of domestically sold goods in hard foreign currency may explain the price level exposure to exchange rate fluctuations in countries with non-credible monetary unit.

Using models, similar to those applied to explanation of exporters' denomination strategy choice; we showed that for domestically selling enterprise it could be profitable to post prices in foreign exchange. The crucial assumption behind the model employed is that of sticky prices. We can justify this assumption for the case of Belarus by authorities' austerity with respect to frequent price changes.

Provided that some firms set their prices in foreign exchange, we can expect overall price level to be dependent on exchange rate either. Empirical treatment seems to support this prediction. We have found that Consumer Price Index deviations around its equilibrium value are closely correlated with exchange rate surprises. This connect seems to last for more than one period. For two other price indices, namely, Producer Price Index, and Agrifood Price Index, the connection is not that strong.

On the eve of exchange rate targeting policy adoption by the National Bank of Belarus, and price liberation, different patterns of pass-through for three indices implies expected shift in the relative prices of different commodity groups.

Estimation results seems to favor hypothesis that pass-through is positively related to currency substitution. Time-varying coefficient estimates of pass-through are positively associated with proxies for currency substitution. However, results are not self-evident so long as fully reliable estimates for popularity of pricing in foreign exchange are not available.

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APPENDICES

Appendix 1

Model of the choice of denomination with costless production

Against the background, described at the beginning of the fourth chapter, a firm faces demand function q(p), and decides whether to denominate in the foreign exchange or in the home currency. Production is costless. DCP profit function is invariant to exchange rate surprises, therefore the choice of denomination depends on convexity of FCP profit function in exchange rate.

$$\Pi^{FCP} = p^{FCP} eq\left(p^{FCP} e\right)$$

Thus,

$$\frac{\partial \Pi^{FCP}}{\partial e} = p^{FCP} q + \frac{\partial q}{\partial p} p^{FCP^2} e$$

$$\frac{\partial^2 \Pi^{FCP}}{\partial e^2} = p^{FCP}\left(\frac{\partial q}{\partial p} p^{FCP} + p^{FCP}\left[\frac{\partial q}{\partial p} + e\frac{\partial\left(\frac{\partial q}{\partial p}\right)}{\partial e}\right]\right) =$$

$$= (p^{FCP})^2\left[2\frac{\partial q}{\partial p} + e\frac{\partial^2 q}{\partial p \partial e}\right] = (p^{FCP})^2\left[2\frac{\partial q}{\partial p} + e\frac{\partial \frac{\partial q}{\partial e}}{\partial p}\right] =$$

$$= (p^{FCP})^2\left[2\frac{\partial q}{\partial p} + e\frac{\partial\left(\frac{\partial q}{\partial p} p^{FCP}\right)}{\partial p^2}\right] = (p^{FCP})^2\left[2\frac{\partial q}{\partial p} + e\left(\frac{1}{e}\frac{\partial q}{\partial p} + p^{FCP}\frac{\partial^2 q}{\partial p^2}\right)\right] =$$

$$(p^{FCP})^2\left[3\frac{\partial q}{\partial p} + p^{FCP} e\frac{\partial^2 q}{\partial p^2}\right]$$

Under regularity conditions (4-10)-(4-11), convexity of FCP profit function and the optimal denomination depend on which of the two opposite effects dominates. There is no general case for convexity or concavity of FCP profit function in exchange rate.

Appendix 2

Model of the choice of denomination with linear demand, constant average cost, and interaction between firms

The residual demand, the cost function and the price level equation are given by, respectively (all constants are assumed to be positive):

$$q(p,P) = \alpha - \beta p + \gamma P$$
$$c(q) = wq$$
$$P = n\tilde{p}^{DCP} + (1-n)\tilde{p}^{FCP} e$$

The wave superscripts mark representative firms' prices. In equilibrium, due to symmetry assumption, all firms post same prices, but at the moment it is crucial to distinguish between any given firm's price and representative firm's price. Each firm takes into account price level when optimizing in price; however, it treats representative firm's price as a given.

Each firm is considered to be too small to influence the price level.

The DCP profit function is

$$\Pi^{DCP} = \left(p^{DCP} - w\right)q = \left(p^{DCP} - w\right)\left(\alpha - \beta p^{DCP} + \gamma P\right)$$

The profit maximization first order condition for a home currency denominating firm is

$$\frac{\partial \Pi^{DCP}}{\partial p^{DCP}} = \alpha - 2p^{DCP}\beta + \gamma P + w\beta = 0$$

$$\hat{p}^{DCP} = \frac{\gamma P + w\beta + \alpha}{2\beta}$$

The second order condition holds, since

$$\frac{\partial^2 \Pi^{DCP}}{\partial p^{DCP2}} = -2\beta < 0$$

The FCP profit function is

$$\Pi^{FCP} = \left(p^{FCP} e - w\right)\left(\alpha - \beta p^{FCP} e + \gamma P\right)$$

The first order condition for a foreign currency denominating firm is equivalent to one for a home currency denominating firm thus confirming that the deterministic price relationship does hold; the second order conditions holds.

$$\frac{\partial \Pi^{FCP}}{\partial p^{FCP}} = \alpha e - 2p^{FCP} e^2 \beta + w\beta e + \gamma P e = 0$$

$$\hat{p}^{FCP} = \frac{\gamma P + w\beta + \alpha}{2\beta e}$$

$$\frac{\partial^2 \Pi^{FCP}}{\partial p^{FCP2}} = -2\beta e^2 < 0$$

Since the overall price level is exposed to exchange rate changes, now profits depend on exchange rate surprises for either denomination strategy.

$$\frac{\partial \Pi^{DCP}}{\partial e} = \left(p^{DCP} - w\right)\gamma(1-n)\tilde{p}^{FCP}$$

$$\Pi^{FCP} = \left(p^{FCP} e - w\right)\left(\alpha - \beta p^{FCP} e + \gamma P\right) =$$
$$\left(p^{FCP} e - w\right)\left(\alpha - \beta p^{FCP} e + \gamma\left[n\tilde{p}^{DCP} + (1-n)\tilde{p}^{FP} e\right]\right) =$$
$$= \alpha p^{FCP} e - w\alpha - \beta p^{FCP^2} e^2 + \beta w p^{FCP} e + \gamma p^{FCP} ne\tilde{p}^{DCP} - w\gamma n\tilde{p}^{DCP} +$$
$$+ \gamma(1-n)\tilde{p}^{FCP} e^2 p^{FCP} - \gamma w(1-n)\tilde{p}^{FCP} e$$

$$\frac{\partial \Pi^{FCP}}{\partial e} = \alpha p^{FCP} - 2\beta e p^{FCP^2} + \beta w p^{FCP} + n\gamma p^{FCP}\tilde{p}^{DCP} +$$
$$+ 2\gamma e(1-n)p^{FCP}\tilde{p}^{FCP} - \gamma w(1-n)\tilde{p}^{FCP}$$

Both derivatives of DCP and FCP profit functions with respect to exchange rate changes are positive if evaluated at optimal prices. We will not exercise the substitution here, since are interested only in checking for relative convexity of FCP profit function conditions.

Since the DCP profit function is linear in the exchange rate,

$$\frac{\partial^2 \Pi^{DCP}}{\partial e^2} = 0$$

Thus, the firm's choice of denomination is fully determined by convexity of FCP profit function in exchange rate. The second order derivative of FCP profit with respect to exchange rate is

$$\frac{\partial^2 \Pi^{FCP}}{\partial e^2} = 2\left[\gamma(1-n)\tilde{p}^{FCP} p^{FCP} - \beta p^{FCP^2}\right]$$

In equilibrium, where all similarly denominating firms set equal prices, this derivative is

$$\left.\frac{\partial^2 \Pi^{FCP}}{\partial e^2}\right|_{p^{FCP}=\tilde{p}^{FCP}} = 2\tilde{p}^{FCP^2}\left[\gamma(1-n)-\beta\right]$$

The logic behind this equation is very clear. Let us consider the case with complementarities. If demand for a given firm's products is closely related to its competitors offers, and large part of competitors embark on the opposite denomination strategy (the first term in the brackets is large), then this firm is likely to incur losses from exchange rate surprise. Consumers easily switch between this firm's products and competitors' goods, leaving the firm exposed to probably unfortunate exchange rate fluctuations that change price of this firm relative to its competitors. In this case the firm is likely to imitate denomination from its competitors. FCP profit function is concave, and DCP dominates.

On the other hand, if firms pricing policy weights more than its competitors actions (the second term in the brackets is large), then the network effects is not likely present in the firm motivation.

Appendix 3

Seasonal adjustment results

Figure A1. Residuals of TRAMO-SEATS seasonal adjustment: market exchange rate

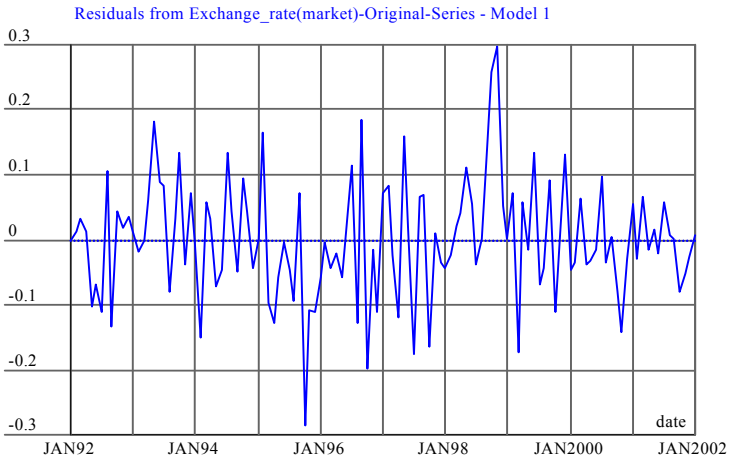


Table A1. Seasonal adjustment diagnostics: market exchange rate

Information on Diagnostics	Model 1
Ljung-Box on residuals	27.12 [0, 32.70] 5%
Forecast error over last year	7.29% [0%, 15.0%]
Percentage of outliers	1.67% [0%, 10.0%]
Combined statistic Q (M1, M3-M11)	0.58 [0, 1]

Figure A2. Residuals from TRAMO-SEATS seasonal adjustment: consumer price index

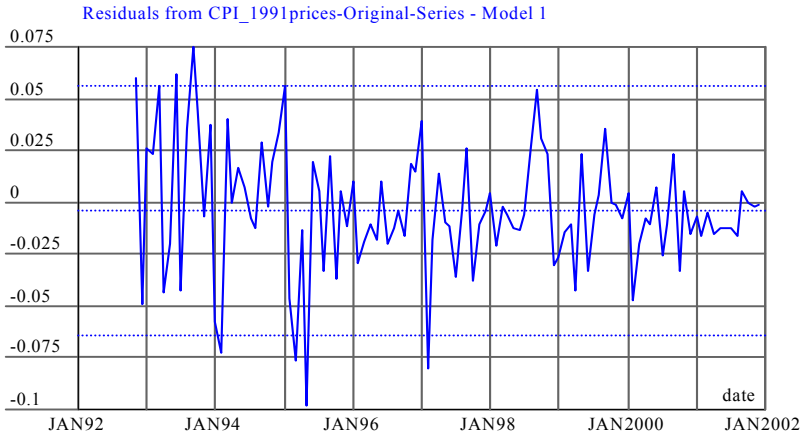


Table A2. Seasonal adjustment diagnostics: consumer price index

Information on Diagnostics	Model 1
Ljung-Box on residuals	48.44 [0, 33.90] 5%
Forecast error over last year	11.77% [0%, 15.0%]
Percentage of outliers	0.83% [0%, 10.0%]
Combined statistic Q (M1, M3-M11)	0.37 [0, 1]

Figure A3. Residuals from TRAMO-SEATS seasonal adjustment: producer price index

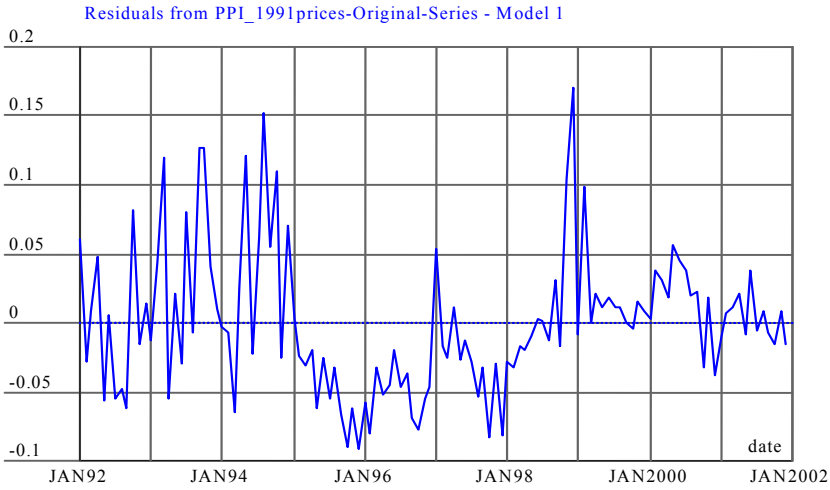


Table A3. Seasonal adjustment diagnostics: producer price index

Information on Diagnostics	Model 1
Ljung-Box on residuals	41.15 [0, 33.90] 5%
Forecast error over last year	7.29% [0%, 15.0%]
Percentage of outliers	2.50% [0%, 10.0%]
Combined statistic Q (M1, M3-M11)	0.65 [0, 1]

Figure A4. Residuals from TRAMO-SEATS seasonal adjustment: agrifood price index

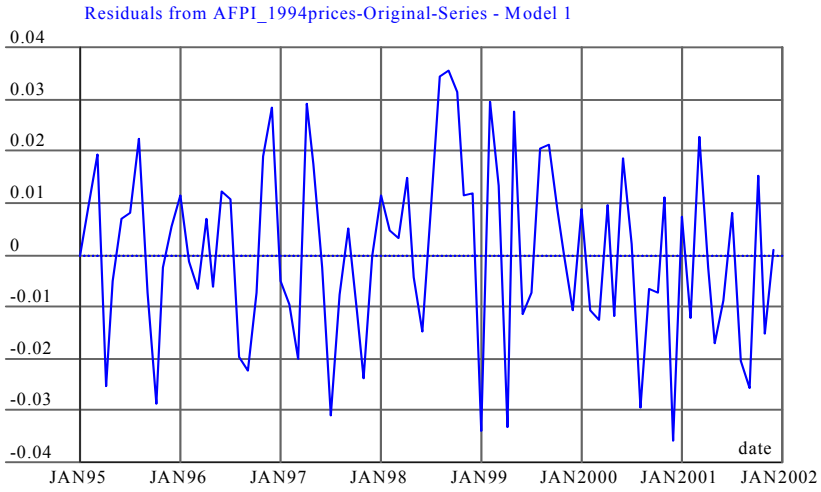


Table A4. Seasonal adjustment diagnostics: agrifood price index

Information on Diagnostics	Model 1
Ljung-Box on residuals	16.52 [0, 32.70] 5%
Forecast error over last year	6.77% [0%, 15.0%]
Percentage of outliers	3.57% [0%, 10.0%]
Combined statistic Q (M1, M3-M11)	0.41 [0, 1]

Figure A5. Residuals from TRAMO-SEATS seasonal adjustment: M1

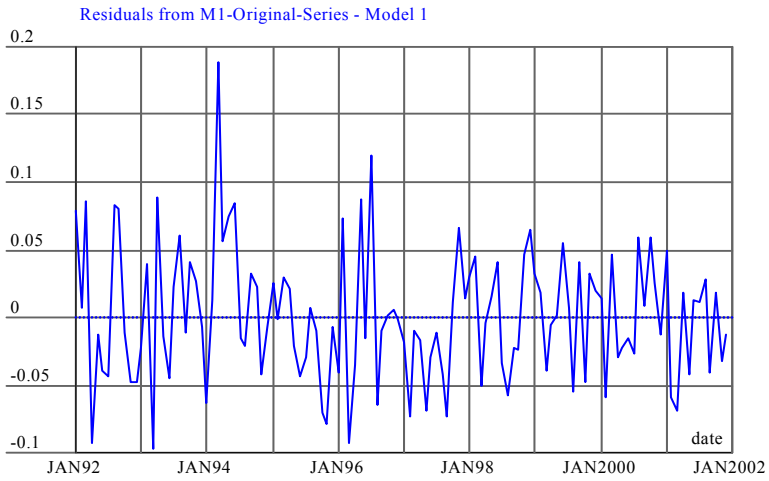


Table A5. Seasonal adjustment diagnostics: M1

Information on Diagnostics	Model 1
Ljung-Box on residuals	18.06 [0, 30.10] 5%
Forecast error over last year	17.50% [0%, 15.0%]
Percentage of outliers	4.20% [0%, 10.0%]
Combined statistic Q (M1, M3-M11)	0.34 [0, 1]

Appendix 4

Fixed coefficient model estimation output

Table A6. Fixed coefficient model for CPI

```
      Source |       SS       df       MS              Number of obs =     116
-------------+------------------------------           F(  7,   108) =    9.03
       Model |  .104492071     7  .014927439           Prob > F      =  0.0000
    Residual |   .17845096   108  .001652324           R-squared     =  0.3693
-------------+------------------------------           Adj R-squared =  0.3284
       Total |  .282943031   115  .002460374           Root MSE      =  .04065

------------------------------------------------------------------------------
cpi          |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
xrate        |
          -- |   .1499796   .0409779     3.66   0.000     .0687543    .2312049
          L1 |    .140214   .0409443     3.42   0.001     .0590552    .2213727
          L2 |   .0480648   .0407516     1.18   0.241    -.0327118    .1288415
          L3 |   .1059061   .0410622     2.58   0.011     .0245138    .1872985
          L4 |   .1159057    .041311     2.81   0.006     .0340202    .1977912
m1           |
          L1 |   .1543179   .0793539     1.94   0.054    -.0029752     .311611
          L2 |   .1279168    .078205     1.64   0.105     -.027099    .2829326
_cons        |  -.0013006   .0037757    -0.34   0.731    -.0087847    .0061835
------------------------------------------------------------------------------

Durbin-Watson d-statistic(  8,   116) =  1.955473

    Variable |       VIF       1/VIF
-------------+----------------------
    L4.xrate |      1.04    0.963797
       xrate |      1.03    0.971283
        L.m1 |      1.03    0.972868
     L.xrate |      1.03    0.973308
    L3.xrate |      1.03    0.975514
       L2.m1 |      1.02    0.978383
    L2.xrate |      1.02    0.984038
-------------+----------------------
    Mean VIF |      1.03


Portmanteau test for white noise
---------------------------------------
Portmanteau (Q) statistic =    37.0063
Prob > chi2(36)           =     0.4223
```

Table A7. Fixed coefficient model for PPI

```
      Source |       SS       df       MS              Number of obs =     117
-------------+------------------------------           F(  6,   110) =   10.96
       Model |  .118524218     6  .019754036           Prob > F      =  0.0000
    Residual |  .198195263   110  .001801775           R-squared     =  0.3742
-------------+------------------------------           Adj R-squared =  0.3401
       Total |  .316719481   116   .00273034           Root MSE      =  .04245

------------------------------------------------------------------------------
ppi          |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
xrate        |
          -- |   .1761649   .0428174     4.11   0.000     .0913108     .261019
          L1 |    .120582   .0425839     2.83   0.006     .0361906    .2049734
          L2 |   .1828368   .0425178     4.30   0.000     .0985766    .2670971
m1           |
          L1 |    .212474   .0811523     2.62   0.010     .0516492    .3732988
          L2 |   .1346731   .0815176     1.65   0.101    -.0268757    .2962219
          L3 |   .1857246   .0811181     2.29   0.024     .0249676    .3464816
_cons        |  -.0006112   .0039251    -0.16   0.877    -.0083899    .0071675
------------------------------------------------------------------------------

Durbin-Watson d-statistic(  7,   117) =   1.65778

    Variable |       VIF       1/VIF
-------------+----------------------
       xrate |      1.03    0.969910
       L3.m1 |      1.03    0.971157
     L.xrate |      1.02    0.980098
       L2.m1 |      1.02    0.981774
    L2.xrate |      1.01    0.985625
        L.m1 |      1.01    0.986957
-------------+----------------------
    Mean VIF |      1.02

Portmanteau test for white noise
---------------------------------------
Portmanteau (Q) statistic =    46.7820
Prob > chi2(36)           =     0.1077
```

Table A8. Fixed coefficient model for AFPI

```
      Source |       SS       df       MS              Number of obs =      84
-------------+------------------------------           F(  2,    81) =    1.55
       Model |  .000901901     2   .00045095           Prob > F      =  0.2181
    Residual |  .023542182    81  .000290644           R-squared     =  0.0369
-------------+------------------------------           Adj R-squared =  0.0131
       Total |  .024444083    83  .000294507           Root MSE      =  .01705

------------------------------------------------------------------------------
afpi          |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
--------------+---------------------------------------------------------------
xrate         |
          -- |   .0306232   .0191027     1.60   0.113    -.0073852    .0686316
          L1 |   .0131653   .0190905     0.69   0.492    -.0248187    .0511493
_cons        |   .0005665   .0018654     0.30   0.762     -.003145     .004278
------------------------------------------------------------------------------

Durbin-Watson d-statistic(  3,    84) =  2.019674

    Variable |       VIF       1/VIF
-------------+----------------------
     L.xrate |      1.00    0.999366
       xrate |      1.00    0.999366
-------------+----------------------
    Mean VIF |      1.00

Portmanteau test for white noise
---------------------------------------
Portmanteau (Q) statistic =    47.7128
Prob > chi2(36)           =     0.0917
```

Appendix 5

Tests for structural stability of the fixed coefficient models

Table A9. Chow breakpoint test for the CPI fixed coefficient model

Chow Breakpoint Test: 1998:02			
F-statistic	3.199005	Probability	0.002830
Log likelihood ratio	26.43278	Probability	0.000885

Figure A6. CUSUM test for the CPI fixed coefficient model

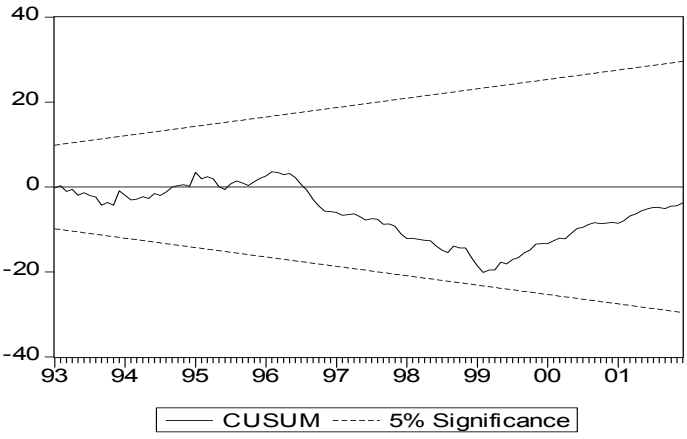


Figure A7. CUSUMQ test for the CPI fixed coefficient model

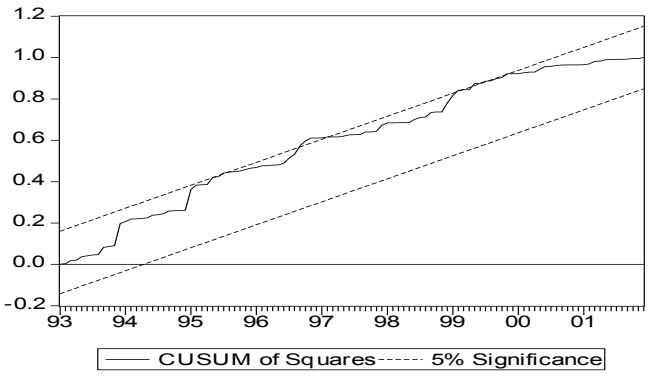


Table A10. Chow breakpoint test for the PPI fixed coefficient model

Chow Breakpoint Test: 1998:02			
F-statistic	1.099008	Probability	0.369464
Log likelihood ratio	8.427768	Probability	0.296388

Figure A8. CUSUM test for the PPI fixed coefficient model

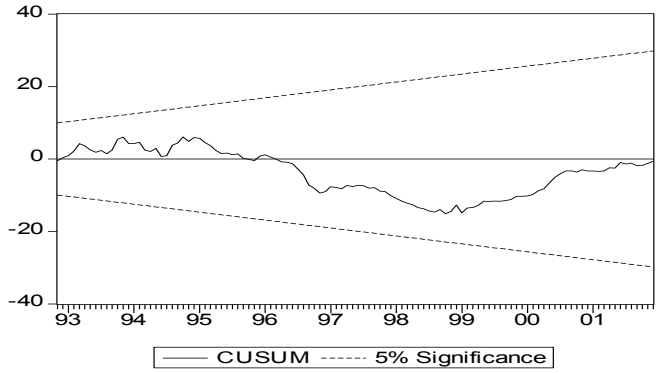


Figure A9. CUSUMQ test for the PPI fixed coefficient model

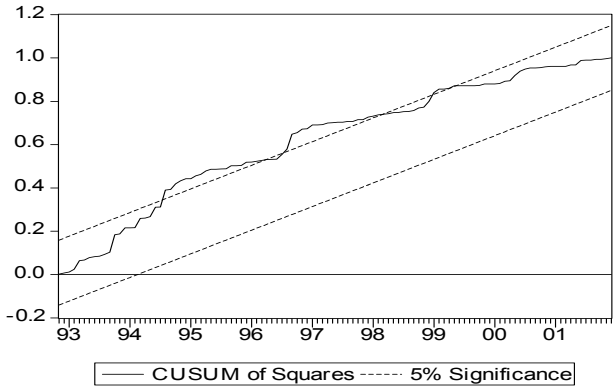


Table A11. Chow breakpoint test for the AFPI fixed coefficient model

Chow Breakpoint Test: 1998:02			
F-statistic	0.314511	Probability	0.814836
Log likelihood ratio	1.010021	Probability	0.798827

Figure A10. CUSUM test for the AFPI fixed coefficient model

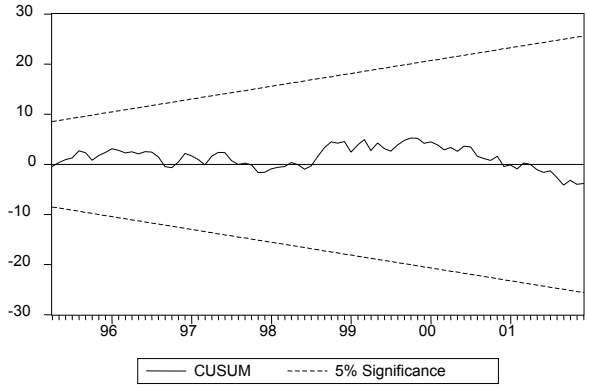
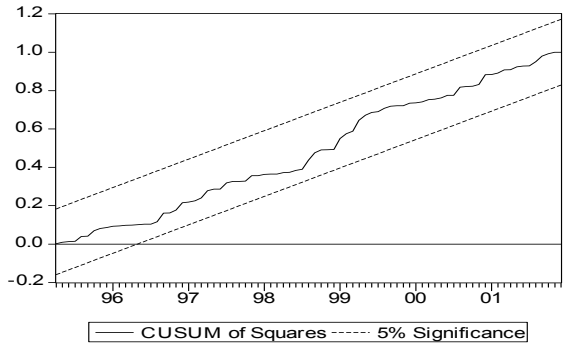


Figure A11. CUSUMQ test for the AFPI fixed coefficient model



Performing the Wald test for structural change with unequal variance

The Wald test for structural change with unequal variance can be implemented by running simple program in STATA (this example considers AFPI fixed coefficient model and test the structural stability across the breakpoint February 1998):

```
regr afpi xrate L.xrate in 37/74
matrix C=e(b)
matrix A=e(V)
regr afpi xrate L.xrate in 75/120
matrix B=e(b)
matrix D=e(V)
matrix W=(C-B)*inv(A+D)*(C-B)'
sca t=el(W,1,1)
display chi2tail(3, t)
```

Table A12. The Wald test for structural change with unequal variance results for fixed coefficient models

Model	Wald test with unequal variance p-value
CPI	**6.424e-79**
PPI	**8.321e-81**
AFPI	**0.79452108**

Appendix 6

Pass-through coefficients estimated by rolling regression

Figure A12. Immediate pass-through into CPI: standard error bar

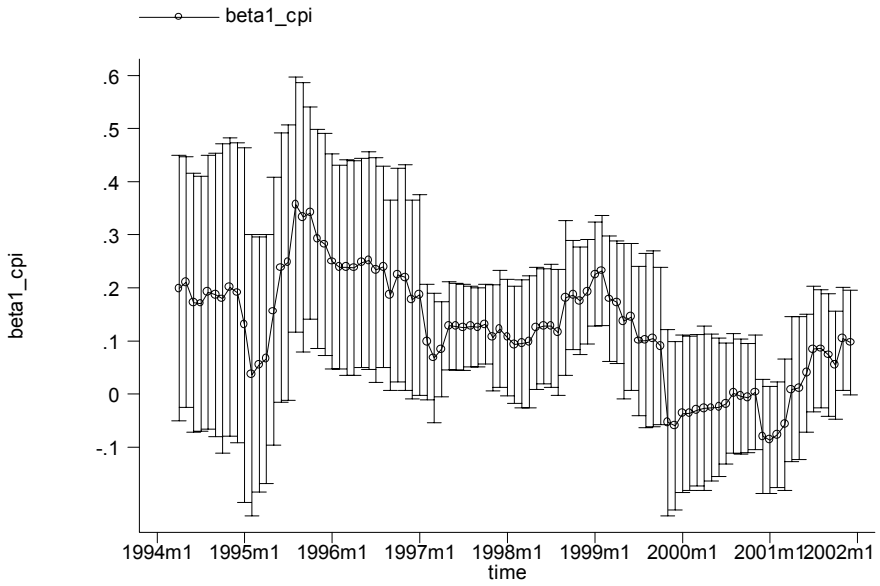


Figure A13. Last month's pass-through into CPI: standard error bar

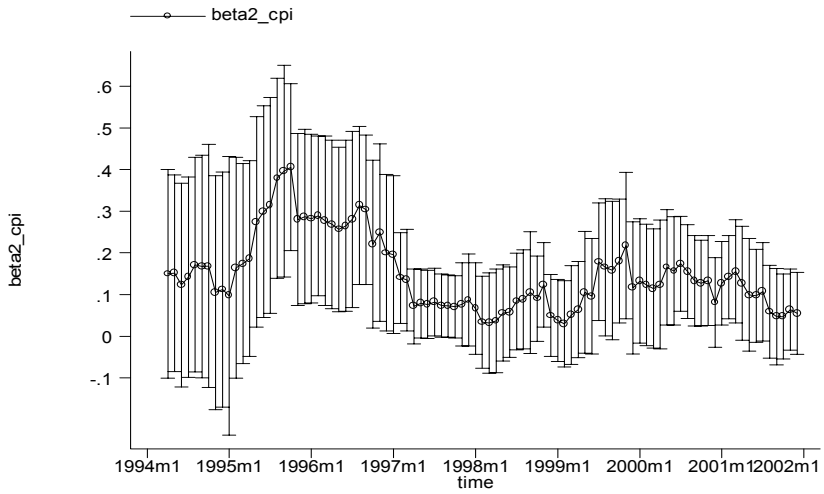


Figure A14. Immediate pass-through into PPI: standard error bar

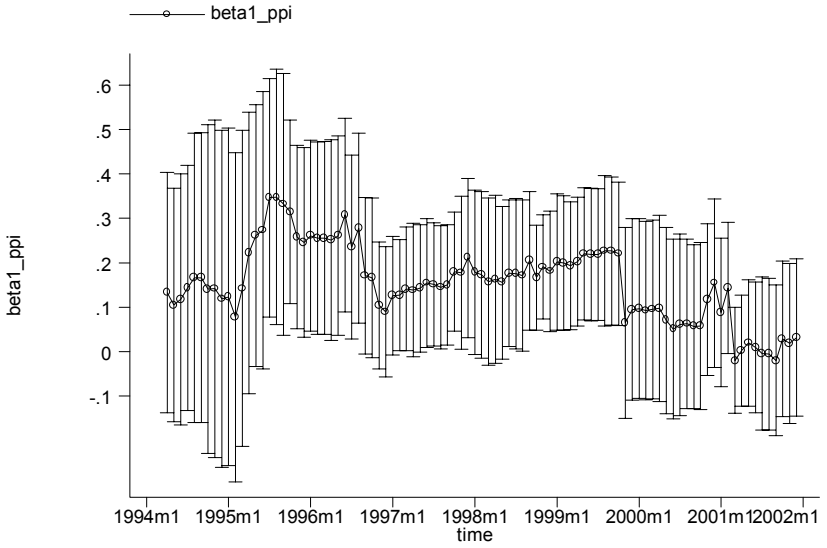


Figure A15. Last month's pass-through into PPI: standard error bar

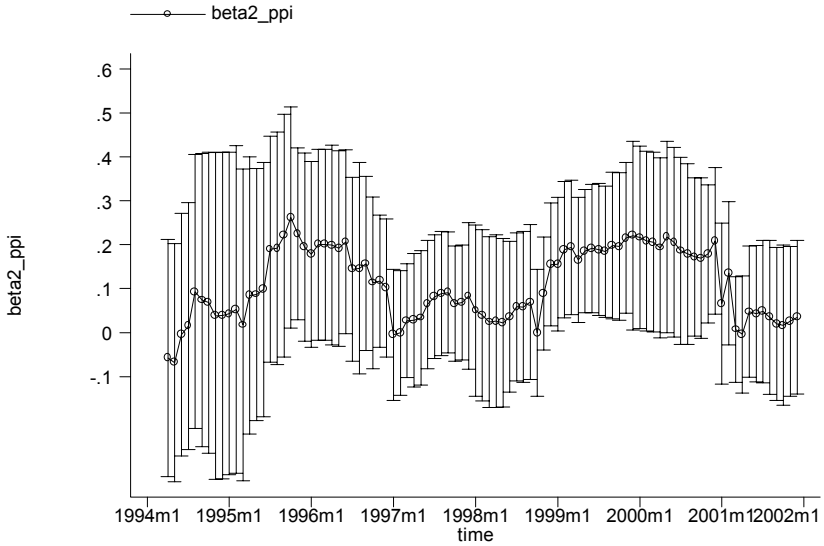


Figure A16. Immediate pass-through into AFPI: standard error bar

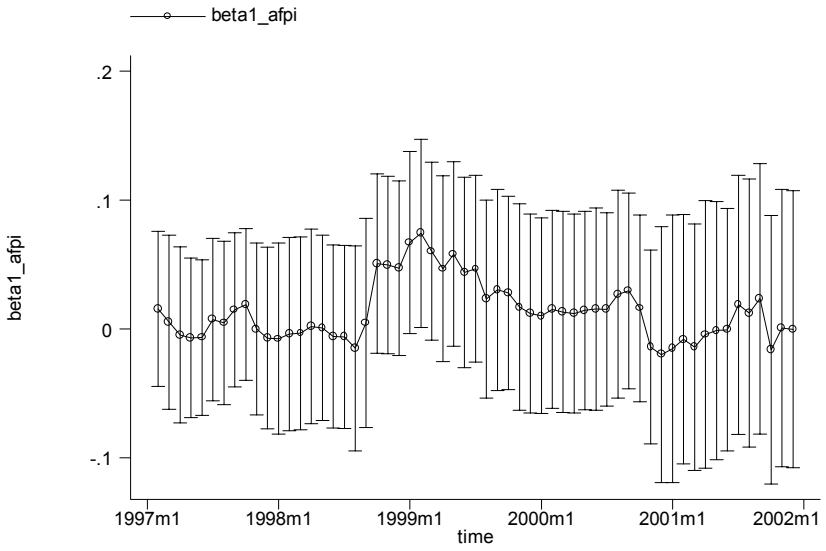
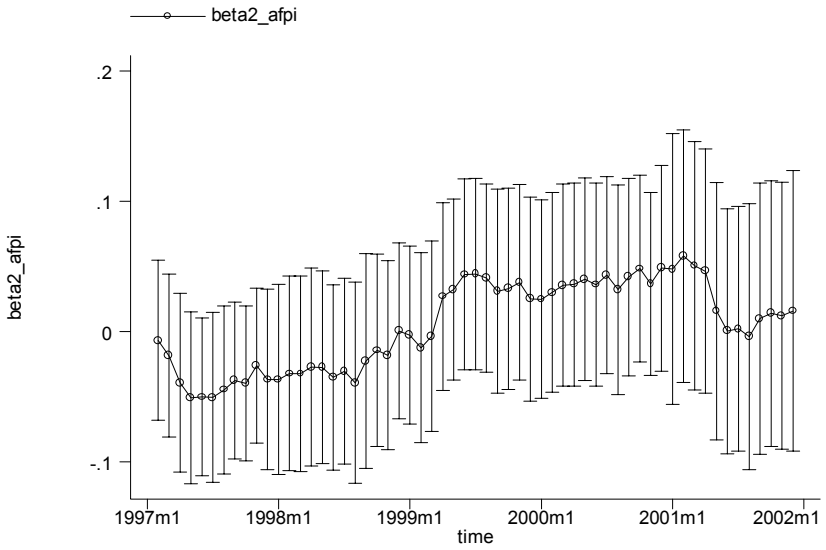


Figure A17. Last month's pass-through into AFPI: standard error bar



Appendix 7

Time-varying parameter model estimation

Table A13. Time-varying parameter model of pass-through into CPI

SSpace: CPI_TVP
Estimation Method: Maximum Likelihood
Date: 05/26/02 Time: 00:17
Model: Time-Varying Coefficient Model
Sample(adjusted): 1992:02 2001:12
Included Observations: 115
Variance of observation equations: Diagonal
Variance of state equations: Diagonal
Convergence achieved after 16 iterations

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.006746	0.002559	2.636063	0.0096
C(2)	0.097382	0.059769	1.629295	0.1062
OBVAR(1,1)	0.000961	0.052800	0.018193	0.9855
SSVAR(1,1)	0.018472	0.016675	1.107759	0.2704
SSVAR(2,2)	0.018985	0.018154	1.045791	0.2980
Final SV1	0.091864	0.339408	0.270658	0.7872
Final SV2	0.026552	0.318681	0.083318	0.9338
Log Likelihood		167.2223		

CPI = C(1) +C(2)*M1+SV1*XRATE+SV2*XRATE(-1)
SV1 = SV1(-1)
SV2=SV2(-1)

R-squared	0.491363	Mean dependent var	-0.000830
Adjusted R-squared	0.486862	S.D. dependent var	0.049679
S.E. of regression	0.035587	Sum squared resid	0.143104
Durbin-Watson stat	1.537671		

Table A14. Statistical description of time-varying coefficients of pass-through into CPI

```
cpi_tvp1
-------------------------------------------------------------
      Percentiles      Smallest
 1%     -.167933       -.265575
 5%     -.112417       -.167933
10%     -.070742       -.166879       Obs                 115
25%      .006769        -.12653       Sum of Wgt.         115

50%      .166393                      Mean           .1926389
                       Largest       Std. Dev.      .2220222
75%      .342209        .662914
90%      .524381        .666497       Variance       .0492939
95%         .569636             .74475      Skewness       .4404494
```

```
99%       .74475        .746391       Kurtosis       2.480634

                          cpi_tvp2
-------------------------------------------------------------
      Percentiles      Smallest
 1%     -.185112       -.231266
 5%     -.153747       -.185112
10%      -.08945       -.180512       Obs                 115
25%      .000255       -.158546       Sum of Wgt.         115

50%      .141452                      Mean           .1601567
                        Largest       Std. Dev.      .2107892
75%      .308607        .575198
90%      .456729        .610494       Variance       .0444321
95%       .56561        .636741       Skewness       .3701507
99%      .636741        .642027       Kurtosis        2.32188
```

cpi_tvp1 – immediate pass-through coefficient

cpi_tvp2 – coefficient of lagged exchange rate pass-through

Table A15. Time-varying parameter model of pass-through into PPI

SSpace: PPI_TVP
Estimation Method: Maximum Likelihood
Date: 05/26/02 Time: 00:28
Model: Time-Varying Coefficient Model
Sample: 1992:01 2001:12
Included Observations: 117
Variance of observation equations: Diagonal
Variance of state equations: Diagonal
Convergence achieved after 12 iterations

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.001195	0.004575	0.261263	0.7944
C(2)	0.034462	0.077124	0.446839	0.6559
OBVAR(1,1)	0.002139	0.024806	0.086212	0.9315
SSVAR(1,1)	0.027783	0.025926	1.071633	0.2862
Final SV1	0.043122	0.431737	0.099881	0.9206
Log Likelihood		175.6744		

PPI = C(1) +C(2)*M1 +SV1*XRATE
SV1 = SV1(-1)

R-squared	0.259288	Mean dependent var	-0.000346
Adjusted R-squared	0.252847	S.D. dependent var	0.052253
S.E. of regression	0.045166	Sum squared resid	0.234598
Durbin-Watson stat	1.481015		

Table A16. Statistical description of time-varying coefficients of pass-through into PPI

```
ppi_tvp
-------------------------------------------------------------
      Percentiles      Smallest
 1%     -.225474       -.321654
 5%     -.101153       -.225474
10%      -.04848       -.157747       Obs                 117
25%      .043122       -.153413       Sum of Wgt.         117

50%       .16874                      Mean           .1785534
                       Largest       Std. Dev.      .1993185
75%      .322693        .611083
90%       .45839        .633975       Variance       .0397279
95%      .558057        .645402       Skewness       .3873168
99%      .645402        .660859       Kurtosis       2.800219
```

Table A17. Time-varying parameter model of pass-through into AFPI

SSpace: AFPI_TVP
Estimation Method: Maximum Likelihood
Date: 05/26/02 Time: 00:43
Model: Time-Varying Coefficient Model
Sample(adjusted): 1995:01 2001:12
Included Observations: 81
Variance of observation equations: Diagonal
Variance of state equations: Diagonal
Convergence achieved after 59 iterations

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.000849	0.001071	-0.792968	0.4303
C(2)	-0.065638	0.026945	-2.435964	0.0172
OBVAR(1,1)	0.000138	0.456422	0.000302	0.9998
SSVAR(1,1)	0.000907	0.182868	0.004958	0.9961
Final SV1	0.025001	0.090414	0.276522	0.7829
Log Likelihood		201.2364		

AFPI = C(1) +C(2)*M1+SV1*XRATE
SV1 = SV1(-1)

R-squared	0.179568	Mean dependent var	-3.05E-06
Adjusted R-squared	0.169183	S.D. dependent var	0.017318
S.E. of regression	0.015786	Sum squared resid	0.019686
Durbin-Watson stat	2.141625		

Table A18. Statistical description of time-varying coefficients of pass-through into AFPI

```
afpi_tvp
-------------------------------------------------------------
      Percentiles      Smallest
 1%     -.122382       -.122382
 5%     -.053867       -.074437
10%     -.036021       -.059206       Obs                  81
25%      -.01828       -.056416       Sum of Wgt.          81

50%      .019467                      Mean            .020864
                        Largest       Std. Dev.       .049301
75%      .049398        .117952
90%      .079015        .118224       Variance       .0024306
95%      .093315        .126753       Skewness      -.0675206
99%       .12817         .12817       Kurtosis       2.867127
```