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Paper by invitation

Exchange Rate Pass-Through and the Frequency of Price Adjustment across Different Inflation Regimes

Summary: The paper explores the link between the inflationary environment and the size of the exchange rate pass-through (ERPT) into domestic prices, as inflation descends from an extreme, second highest and second longest hyperinflation in the 20th century, to high and then moderate inflation in Serbia. We found that ERPT decreases with a decline in the inflation level, variability and persistence, thus supplementing findings previously acquired in panel studies across countries. Our findings can be explained by surging empirical evidence on state contingent behavior of pricing, which indicates a sharp increase in the frequency of price adjustment as one moves from moderate, via high to hyperinflation, suggesting that the degree of price rigidities is a key determinant of the size and speed of ERPT. ERPT estimates are embedded in careful analysis of inflation episodes in Serbia, showing that hyper and high inflation episodes subscribe to the same, fiscal explanation, as opposed to the moderate inflation ones, where supply and demand shocks have been the main inflation drivers.

Key words: Pass-through, Exchange rate, Inflation, State contingent behavior of pricing.

JEL: E31, E52, F41.

This paper examines the link between the inflationary environment and the size of the exchange rate pass-through (ERPT) into domestic prices, across extremely diverse inflationary episodes and explores whether the size of ERPT could be explained by the related changes in the pace of price adjustment. In doing so, we combine two different sets of empirical findings. First, ERPT is assessed for an extreme period of hyperinflation, second highest and second longest hyperinflation in the 20th century (in the early 1990s), then for high inflation in the 1990s, and finally for a period of moderate inflation in the 2000s, all within Serbia. The obtained findings are then complemented with another set of international empirical evidence showing that the frequency of price adjustments increases as one moves from moderate, via high to hyperinflation (cf. Etienne Gagnon 2009 and Fernando Alvarez et al. 2013). Combining these two strands of empirical findings should enable us to answer the question posed above, i.e., whether degree of price rigidities is a main determinant of ERPT (cf. Charles Engel 2002). Moreover two sources of empirical evidence used

should render general bearing to the obtained results, i.e., beyond the specific inflationary episodes examined.

Accordingly, this paper examines first whether the size and speed of ERPT varies with level, variability and persistence of inflation and currency depreciation across extreme ranges of inflation in one country over time, thus supplementing some previous evidence in panel studies across countries. Secondly, as the considered episodes include moderate, high to severe hyperinflation, they represent a good laboratory to explore the relation between inflation, frequency of price changes and the size/speed of ERPT, thus testing whether sticky prices are a key determinant of ERPT.

The paper is organized as follows. Section 1 gives a literature survey. In Section 2 inflation episodes are analyzed suggesting that hyper and high inflation share a common cause and pattern that is sharply different from those in moderate inflation. This section also presents level, variability and persistence of inflation and currency depreciation across episodes. Drawing on analysis in Section 2, inflation episodes are modeled and ERPT coefficients estimated in Section 3. Section 4 shows that ERPT co-moves with level, variability and persistence of inflation across episodes, and offers an explanation by referring to the empirical evidence on state contingent behavior of pricing, specifically across low to hyperinflation episodes. Conclusions are presented in Section 5.

1. A Literature Survey

The paper draws on three strands of recent research. First, empirical evidence has been supplied showing that ERPT varies with the level, variability and persistence of inflation and currency depreciation. In particular, Joseph E. Gagnon and Jane Ihrig (2004) examined the effects of inflation level and variability on the size of pass-through in a panel of 20 industrial countries, finding that both factors affect the pass-through coefficient, although inflation variability explains it better than the inflation level does. Moreover, their investigation into whether a switch to a more stable monetary regime, and in particular the adoption of inflation targeting, lends to a decline in pass-through received support. The subsequent research for developed countries endorsed this result (cf. Jeannin Bailliu and Eiji Fujii 2004; Ihrig, Mario Marazzi, and Alexander D. Rothenberg 2006; Toshitaka Sekina 2006). Additionally, John B. Taylor (2000) supplied some evidence for the US showing that a decline in inflation persistence led to a decrease in exchange rate pass-through.

Empirical evidence for developing countries concurs by and large with the above evidence for developed economies. Thus, in a sample that contains both developed and developing countries, Frankel A. Jeffrey, David C. Parsley, and Shang-Jin Wei (2005) found, among other things, that pass-through is significantly higher during periods of high inflation, and that decreasing inflation in the 1990s can account for the fall in pass-through. Moreover, they obtained that the monetary environment in developing countries is particularly important in explaining the decline of pass-through into domestic prices. Michael Devereux and James Yetman (2010) found in a large sample of developing and developed countries that ERPT increases with inflation level and variability and exchange rate variability. Bank for Interna-

tional Settlements (2002) also links the low pass-through in developing countries to a decline in long-run inflation. Ehsan U. Choudhri and Dalia S. Hakura (2006), in a sample of both developed and developing countries, documented that a low inflationary environment leads to low exchange rate pass-through, and in addition that the inflation rate dominates other variables in explaining the differences in pass-through across diverse inflation regimes.

A second strand of literature that this paper relies on examines main determinants of ERPT, addressing it as macroeconomic phenomenon and attributes key role to sticky prices, suggesting that e.g. low ERPT is due to rigid prices (cf. Charles Engel 2002; Ehsan U. Choudhri, Hamid Faruqee, and Dalia S. Hakura 2005; and Devereux and Yetman 2010). Some supporting evidence for this hypothesis is offered by Choudhri, Faruqee, and Hakura (2005) and Devereux and Yetman (2010). The degree of price rigidities however could be associated with monetary policy stance, thus linking the size of ERPT with the latter (cf. Taylor 2000; and Frederic S. Mishkin 2008).

This leads us to a third, recently surging strand of research that examines empirically the behavior of prices using micro data, exploring issues such as the gradual adjustment of prices to shocks (cf. Gagnon 2009; Gita Gopinath and Oleg Itskhoki 2010; and Alvarez et al. 2013). Since the exchange rate shock is well-defined and sizable cost shocks, this brings us to an issue of the exchange rate pass-through into price level. A relevant empirical finding of this literature for our paper is that during high inflation, and/or high devaluations, the frequency of price adjustments sharply increases (see also Ariel Burstein and Gopinath 2013). Consequently, under high inflation prices become less sticky and the exchange rate shock should faster spill-over into price level, leading to swift/large ERPT.

2. Inflation Episodes in Serbia: A Background

2.1 Inflation Episodes: Causes, Drivers and Patterns

Serbia experienced a turbulent high inflation history in the 1990s, starting with long and extreme hyperinflation followed by high inflation. In the 2000s, extensive reform and macro-stabilization efforts curbed high inflation and laid the foundation for maintaining low inflation.

Hyper and high inflation in 1990s basically share the same cause, driver and pattern, i.e. large fiscal deficits (open or disguised) were monetized leading to excessive money growth that directly propelled currency depreciation and, via the latter, inflation. Thus, these episodes conform to fiscal view of inflation.

The decisive factor that triggered hyperinflation in Serbia was disintegration of former Yugoslavia in the summer of 1991, and the ensuing arm conflicts that Serbia was involved in. As a consequence of the latter, a UN embargo on foreign trade was introduced in the summer of 1992, further worsening Serbia's economic and fiscal positions. The resulting fiscal deficit was monetized by excessive money printing, which triggered hyperinflation during the period of 1992-93 (cf. Pavle Petrović, Željko Bogetić, and Zorica Vujošević (Mladenović) 1999). This hyperinflation was among the most severe in the 20th century, being lower only than the Hungarian

hyperinflation from 1945-46, and shorter only than the Russian one in the 1920s. Inflation started mounting in 1991, surpassing Cagan's 50% benchmark in February 1992, and finally was halted in the beginning of February 1994.

The exchange rate in hyperinflation is directly determined by its fundamental element – the money supply, i.e. there is evidence that present value monetary model of exchange rate does hold in the Serbian hyperinflation episode (cf. Petrović and Mladenović 2000), or in the German one (Tom Engsted 1996). Once set by the money supply, the exchange rate determines the price level since in hyperinflation foreign currency is almost universally used as a unit of account due to extreme dollarization. This pattern is tested while ERPT is evaluated.

In the 1990s, a hyperinflation episode in Serbia was followed by a protracted period of high inflation. The exchange rate based stabilization was enacted at the end of January 1994, and hyperinflation stopped immediately, i.e. in the beginning of February. Effectively, the program relied simply on fixing the exchange rate, and riding on the consequent re-monetization (i.e. increase in money demand from the extremely low level in hyperinflation), and the inverse Tanzi effect (a rise in real tax revenues due to the halt in inflation). The increase in money supply that matched the rise in its demand (re-monetization) was used to finance the fiscal deficit (e.g. pensions) and the quasi-fiscal one through soft loans to public enterprises (e.g. Electricity Company and other utilities). Thus, stabilization was neither credible nor sustainable as it was not accompanied by fiscal and other structural reforms, notably privatization, bank restructuring and labor market reforms. Transition that started in 1990 within former Yugoslavia was stalled, leaving Serbia with a dominant state owned sector. Therefore, this non-credible stabilization soon led to new high inflation. The continued UN trade embargo further added to instability.

Specifically, inflation and depreciation reemerged by the end of 1994 when the rise of money demand was overestimated by the central bank and the government, placing increasing pressure on additional money supply increase. The latter triggered currency depreciation and inflation again. As shown in Table 1 below, the average annual inflation rate was above 40% through mid-1998, but nevertheless the underlying inflation was higher, i.e. around 50%. Namely, annual inflation dropped to 9% in 1997, thanks to a large inflow of capital from the sale of 49% of Telecom Serbia, while the privatization proceeds were used to cover fiscal (pensions) and quasi-fiscal deficits. This temporarily halted deficit monetization, and stabilized the exchange rate and inflation in 1997.

Thus, we conjecture that upon non-credible stabilization, the same inflation pattern observed in hyperinflation remained in place in the mid-1990s, just less extreme. Namely, we hypothesize that money supply, while monetizing fiscal deficits, propels currency depreciation and inflation, that the exchange rate is directly determined by its fundamental – money supply, and that due to still high dollarization currency depreciation spills over completely into inflation. This fiscal view of inflation will be tested and within that framework ERPT will be evaluated.

As to the monthly sample to be used, it begins in June 1994, in order to skip the first few months of stabilization, and ends in June 1998, due to the looming armed conflict in Kosovo. Namely, the conflict escalated in the summer of 1998 and

culminated with the NATO bombardment in the spring of 1999. This was accompanied by increased price controls and other administrative measures in the economy that lasted through September 2000.

Finally, in the 2000s, after a decade of high inflation, Serbia succeeded in taming inflation. Upon political turnaround in October 2000, the country opened up, immediately concluding a stand-by agreement with the IMF, and as a latecomer commenced comprehensive economic reforms extensively supported by international financial organizations. After launching macroeconomic stabilization and initiating structural reforms at the beginning of 2000s, inherited high inflation was curbed and monetary accommodation halted. Structural reforms i.e. privatization, bank restructuring, fiscal and labor market reforms, etc. significantly hardened budget constraints in Serbia during the 2000s.

Stabilization commenced in October 2000 with across the board removal of price controls which mounted, as explained above, in the time of the Kosovo conflict. This was followed, in the first half of 2001, by large administrative adjustments of utility prices. At the same time, extensive tax reform was enacted. These shocks, combined, pushed inflation up, particularly from the last quarter of 2000 through mid-2001.

The stabilization program was effectively an exchange rate based program as, although the official exchange rate regime was a managed float one, the rate remained fixed for two years (through 2002). Large real appreciation was experienced in that period. This was followed by a more flexible arrangement, resulting first in nominal and real exchange rate depreciation, and then in real appreciation, and eventually nominal appreciation. The latter has been the first experience with nominal appreciation in Serbia in a long period of time. Nominal appreciation was a consequence of large inflows of foreign capital, and the central bank decision to allow almost a free float of currency while announcing an adoption of inflation targeting in mid-2006. Thus, there have been a lot of variations both in exchange rate regimes, and in nominal and real rates lending opportunity to thoroughly assess the size of pass-through.

Inflation sharply decreased in the 2000s, from 50% to 12% in the 1990s as a consequence of structural changes indicated above. Nevertheless, it was still double digit, and was driven both by aggregate demand and supply shocks. Thus, large inflow of capital, facilitated by foreign owned privatized banks and by large privatization in the real sector via foreign direct investments, led to sharp increases in aggregate demand, output and current account deficit. This coincided with inflation outburst in 2005 and lasted through mid 2006. The subsequent nominal appreciation of the currency tamed this inflation by the end of 2006. Yet another surge of inflation in Serbia occurred in the second half of 2007 and through mid 2008, triggered by a sharp rise in the world food prices as well as an increase in oil price¹. At the same time, Serbia recorded a higher increase in real wages in the 2000s (12% average per year) relative to productivity growth, hence exercising constant pressure on inflation. Thus, inflation triggers in Serbia in the 2000s were mostly the same ones as in other emerg-

¹ For inflation dynamics and more broadly macroeconomic developments in Serbia see Foundation for the Advancement of Economics (2005-2009).

ing European economies i.e. overheated economy due to large inflow of capital (cf. Abdul Abiad, Daniel Leigh, and Ashoka Mody 2009) and food and oil price shocks, but, nevertheless, inflation surge was more pronounced in Serbia.

Therefore, while modeling the inflation episode in the 2000s, and assessing ERPT within it, we shall try to capture both aggregate supply and demand shocks.

The monthly sample employed starts in July 2001 in order to avoid the impact on price level of large administrative price adjustments and extensive tax reform in the first half of 2001, and ends in July 2008 i.e. before financial crisis hit Serbia triggering sharp currency depreciation.²

2.2 Some Stylized Facts on Inflation and Currency Depreciation

As explained in Section 1 above, there is mounting evidence that the level, variability and persistence of inflation, and in some cases currency depreciation, affect the size and speed of ERPT. Therefore, in this section, we shall examine how these attributes of inflation evolve across the above analyzed episodes in Serbia.

Table 1 reviews the level and variability of inflation and currency depreciation in the three, previously defined, inflation episodes in Serbia.

Table 1 Inflation and Exchange Rate Depreciation: Level and Variability

	Inflation	Exchange rate depreciation
Hyperinflation: 1990.12 – 1993.10	64.4 (76.8)	74.1 (86.3)
High inflation: 1994.6 – 1998.6	3.4 (3.2)	3.6 (5.7)
Moderate inflation: 2001.7 - 2008.7	1.0 (0.7)	0.3 (1.2)

Note: Mean per month with the corresponding standard deviations in the brackets. Exchange rate depreciation is used for hyperinflation, while foreign, German and EU, inflation is respectively added in the case of the other two regimes. Rates are continual i.e. difference of ln, and they are lower than the customary used discrete ones; the difference between the two is larger for the higher rates.

Source: Authors' calculations.

As shown in Table 1, average monthly inflation, measured as a log difference³, descended from an enormous scale in hyperinflation to high and then moderate ones, and the same pattern and similar magnitudes were recorded by currency depreciation. The variability of both inflation and currency depreciation, measured with standard deviations reported in the brackets, also followed the same decreasing trend from high size in hyperinflation to low one in moderate inflation.

Persistence of inflation and currency depreciation sharply dropped from high level in hyperinflation to moderate levels in the other two episodes in Serbia. Thus, in hyperinflation, both inflation and currency depreciation, as well as money supply growth, were non-stationary I (1) processes, and hence highly persistent (cf. Petrović,

² Effect of subsequent sharp currency depreciation on the size of exchange rate pass-through during the crisis in Serbia is thoroughly explored in Mladenović and Petrović (2014). The result relevant for this paper is that pass-through coefficient remained stable after including period of severe depreciation in the sample, i.e. 0.24.

³ Rate of change measured as ln difference is lower than the usually reported discrete ones, and the deviation between the two is larger for the higher rates, e.g. average monthly inflation of 64.4% in Table 1, would be as large as 90%.

Bogetić, and Vujošević (Mladenović) 1999), while their persistence decreased in the other two episodes as they became stationary processes.

Persistence of stationary process is assessed using various sums of MA coefficients⁴. The latter are obtained by estimating the ARIMA model, spectral density and variance ratio test respectively, and they all give similar results (cf. Table 2), showing that findings are robust.

Table 2 Persistence of Inflation and Currency Depreciation

Infinite sum of MA coefficients that are calculated from estimated ARIMA model		
	Inflation	Exchange rate depreciation
High inflation of 1994 – 98	4.54	2.45
Moderate inflation in the 2000s	1.12	4.01
Truncated sum of MA coefficients that are calculated from estimated ARIMA model		
	Inflation	Exchange rate depreciation
High inflation of 1994 – 98	4.40	2.39
Moderate inflation in the 2000s	1.12	3.89
Sum of MA coefficients based on estimated spectral density function		
	Inflation	Exchange rate depreciation
High inflation of 1994 – 98	3.47	1.77
Moderate inflation in the 2000s	1.95	2.39
Truncated sum of MA coefficients based on variance ratio test		
	Inflation	Exchange rate depreciation
High inflation of 1994 – 98	3.30	1.59
Moderate inflation in the 2000s	1.51	2.61

Source: Authors' calculations.

Inflation persistence markedly dropped in moderate inflation compared to the high one, while the persistence of currency depreciation increased slightly. Thus, from hyperinflation to a moderate one, persistence of inflation clearly decreased while the corresponding result for depreciation was ambiguous.

2.3 Data Definitions and Methodology

We use monthly series expressed in natural logarithms hence, their first difference represents the rate of change. Retail price index (p) is used in all three episodes while examining inflation (Δp), and the source is Statistical Office of Serbia. Money supply (m) represents (ln of) M1, and the source is the National Bank of Serbia (NBS). The exchange rate (e) for the 1990s, i.e. for hyper and high inflation episodes, is black market exchange rate of domestic currency vs. the German mark (Din/DM). The black market rate greatly deviated from official fixed rates in the '90s, and apart from

⁴ It is a standard way to measure persistence, cf. Terence C. Mills and Raphael N. Markellos (2008), pp. 124-126.

a small fraction of government subsidized transactions, all other transactions were carried out on at the black market rate. Consequently, this rate is widely followed and reported in newspapers, and later on in the '90s even by the NBS, where the data for this research is derived from. The choice of the German mark is due to its traditional use in the former Yugoslavia, and subsequently in Serbia, as safe haven for savings and as unit of account, owing to large remittances coming from (West) Germany. In the 2000s, dinar became convertible, and hence official exchange rate to euro is used, while the source is the NBS.

The exchange rate is corrected by foreign inflation while exploring the high and moderate inflation episodes, i.e. $epe = e + pe$, while for the hyperinflation we use just the exchange rate (e) as its excessive increase overwhelms the increase in foreign price level (pe). Foreign inflation is captured by the German one in the 1990s, and the EU in the 2000s.

The (ln of) of average wage rate (w) is taken from the Statistical Office of Serbia, while $poil$ is (ln of) the price in domestic currency of the Russian crude oil that Serbia dominantly imported.

The output gap refers to non-agriculture GDP, the latter being available at quarterly frequency from the Statistical Office of Serbia. We transformed the quarterly GDP data into monthly series following monthly dynamics of composite index constructed as weighted average of index of industrial production and retail sale index. The output gap represents deviation of the non-agriculture seasonally adjusted GDP from its HP trend. Seasonal adjustment was obtained by a procedure available in TRAMO/Seats software.

As to the methodology used, we base our analysis on vector autoregressive (VAR) model. It provides framework for conducting the Johansen cointegration test and then estimation of cointegration vectors upon their identification has been achieved (Soren Johansen 1996; Katarina Juselius 2006), as is extensively shown in Section 3.2 below. Cointegration coefficient on exchange rate in a price equation gives then an estimate of the long-run ERPT. In addition, cointegrated VAR model is employed to estimate the path of impulse response functions. Calculation of these functions is based on the Cholesky triangular decomposition of the residual covariance matrix. Cumulative ERPT, both in the short and long run can be assessed by employing impulse response function of the price level (p) and the exchange rate (epe or e). Specifically, ERPT is determined by dividing the impulse response of the price level by the response of the exchange rate after j months, where both responses are to the initial exchange rate shock.⁵

3. Empirical Results

3.1 Hyperinflation of 1992-93: Monetizing Fiscal Deficit

As conjectured above, in hyperinflation money supply directly determines the exchange rate, while subsequently the latter sets the price level. Monetization of fiscal

⁵ Thus pass-through over j months is calculated as p_{t+j}/e_{t+j} , where p_{t+j} and e_{t+j} are respectively impulse responses of the price level and the exchange rate to the initial exchange rate shock.

deficit propels the money supply, and it is expected to be exogenous with respect to the exchange rate and the price level.

While exploring the pattern above, a monthly sample is used that starts in December 1990 when new inflation was triggered off, and ends in October 1993 with the last reliable observation of the price level. The sample is not particularly long but this is common for all analyses of hyperinflation, as they are not a long-lived phenomenon.⁶

All considered variables – logs of the money supply (m), the exchange rate (e) and the retail price index (p) – are I(2), and hence their growth rates are I(1). In a system of money growth (Δm), exchange rate depreciation (Δe) and inflation (Δp), two cointegrating vectors are found, and upon identification (cf. Johansen 1996; Juselius 2006) the following system is obtained and estimated.⁷

$$\Delta p = 1.17\Delta e \quad (1)$$

$$\Delta e = 0.96\Delta m. \quad (2)$$

Money growth is weakly exogenous in the cointegrated system above, and represents stochastic trend that drives both currency depreciation and inflation. This concurs with fiscal explanation of inflation. Money supply, being the sole exchange rate fundamental in hyperinflation, directly determines it (cf. Eq. 2), hence, validating monetary model of exchange rate. As almost all prices are quoted in foreign currency (dollarization), once the exchange rate is set (Eq. 2), it subsequently determines price level in domestic currency (Eq. 1). Thus, due to dollarization complete pass-through from the exchange rate to price level is obtained in hyperinflation (cf. Eq. 1).

The speed of adjustment towards complete pass-through can be assessed by estimating cumulative ERPT, while employing cointegrated VAR model of Δm , Δe and Δp (see Table 3).

Table 3 Cumulative Pass-Through from Exchange Rate to Prices: Impulse Response (ρ_{t+j}/e_{t+j})

January 1991 – October 1993				
Ordering	1 month	2 months	3 months	4 months
Δm - Δe - Δp	0.23	0.87	0.90	1.14

Note: Baseline VAR model is of order 3. Estimated impulse response function is based on the Cholesky decomposition of the residual covariance matrix from the corresponding vector equilibrium error correction model. Decomposition follows the pattern of estimated Equations (1) and (2): Δm is exogenous and affects Δe , while Δe subsequently influences Δp .

Source: Authors' calculations.

As expected, ERPT is swift in hyperinflation, i.e. complete spill-over from currency depreciation (Δe) into inflation (Δp) takes 3.5 months.

⁶ Cf. e.g. Mark P. Taylor (1991) and Engsted (1994, 1996).

⁷ Cf. Petrović, Bogetić, and Vujošević (1999), Eqs. 3 and 4, p. 347.

3.2 High Inflation in the 1990s: Non-Credible Stabilization

In the mid-1990s, hyperinflation was tamed but, as explained above, its cause was not rooted out. Specifically, we shall explore whether high inflation holds the same pattern as the one in hyperinflation, i.e. whether money supply drives currency depreciation and, through it, inflation.

The methodology used, as above, is cointegration analysis (cf. Johansen 1996; Juselius 2006) while the sample runs from June 1994 to June 1998. In the first step, among three I(1) variables: the (logs of) price level (p), exchange rate (epe) and money supply (m), two cointegrating vectors are found (cf. Table 4).

Table 4 Cointegration between the Price Level (p), the Exchange Rate (epe) and Money Supply (m)

June 1994 – June 1998		
Rank	Eigenvalue	Trace test
$r=0$	0.533	50.93
$r\leq 1$	0.250	15.95
$r\leq 2$	0.058	2.74

Note: A constant term enters the VAR model unrestrictedly. There are three lags in the VAR model. The 5% critical values for the trace test are: 29.80 for $r=0$, 15.41 for $r\leq 1$ and 3.84 for $r\leq 2$ (Jonathan G. Dennis 2006).

Source: Authors' calculations.

Testing for weak exogeneity among these cointegrated variables shows that only money supply is weakly exogenous (cf. Table 5), thus indicating, as assumed by the fiscal view, that money drives the other two variables.

Table 5 Testing for Weak Exogeneity under the Assumption of Two Cointegration Vectors

Critical value at the 5% level, $\chi^2(2)$	Prices	Exchange rate	Money
5.99	12.68(0.00)	29.71(0.00)	4.41(0.11)

Source: Authors' calculations.

Estimates of cointegrated vectors (cf. Table 6) indicate that the first vector (β_1) may represent the relation between the (logs of) exchange rate (epe) and money supply (m), since the coefficient on the price level (p) is close to zero (0.025). Similarly, the second vector (β_2) may depict the relation between the (logs of) price level (p) and the exchange rate (epe).

Table 6 Estimated Cointegration Vectors

Variable	β_1	β_2
Prices	0.025	1
Exchange rate	1	-0.976
Money	-0.913	-0.001

Source: Authors' calculations.

As the next step, we impose the corresponding restrictions on cointegration vectors and test whether they hold. Thus, coefficients on price level and money supply in

the first and the second cointegration vectors respectively are set to zero. In the second vector we set coefficient on exchange rate to be one thus assuming that the long-run ERPT is complete (equal to 1). Finally, we impose zero on the adjustment coefficients for the money growth equation, as it is obtained above (cf. Table 5) that the money supply is the only (weakly) exogenous variable. The VAR model is estimated under these restrictions and the results are reported in Table 7.

Table 7 Cointegration VAR Model Estimated under Imposed Restrictions

Estimated cointegrated vectors		
Variable	β_1	β_2
Prices	0	1
Exchange rate	1	-1
Money M1	-0.856	0
Estimated vectors of adjustment coefficients		
Equation	α_1	α_2
The first difference of:		
Prices	0.039 (2.03)	-0.114 (-3.78)
Exchange rate	-0.241 (-5.89)	-0.065 (-1.00)
Money M1	0	0

Note: *t*-ratios are in parentheses.

Source: Authors' calculations.

Imposed restrictions are tested and accepted (not rejected): $\chi^2(3)=4.47(0.22)$. Thus, the identified cointegrating model reads as follows:

$$p = epe \quad (3)$$

$$epe = 0.86m \quad (4)$$

showing that the same pattern is found in the high inflation of mid 1990s as in hyperinflation (cf. Eqs 1 and 2). Among three $I(1)$ variables: the (log of) price level (p), exchange rate (epe) and money supply (m), two cointegration vectors are found, representing the equation between price level and exchange rate (3), and exchange rate and money supply (4) respectively. The significance of the adjustment coefficients (cf. Table 7) indicate that price level (p) is endogenous in Eq. 3, and exchange rate (epe) in Eq. 4. Moreover, the presence of two cointegration vectors among three variables implies that there is one stochastic trend that drives the system (cf. Johansen 1996), and we found that the trend is money supply. Once again, as in hyperinflation, we found evidence supporting the fiscal view of inflation, i.e. that excessive money growth drives inflation, while monetizing fiscal and quasi fiscal deficits.

In summary, exogenous money supply determines directly the exchange rate (cf. Eq. 4), lending support to the monetary model of exchange rate, while subse-

quently exchange rate determines the price level (cf. Eq. 3). The latter (Eq. 3) also gives an estimate of the long-run ERPT, suggesting that it is complete i.e. equal to 1.

An alternative way to assess the long-run ERPT, but also the short-run as well as the speed of pass-through, is to use impulse response in a cointegrated VAR model containing (log of) money supply (m), exchange rate (epe) and price level (p) to estimate cumulative pass-through coefficients. Ordering of variables in the estimated model is set according to the cointegrating model identified above, i.e. m is exogenous determining epe , and the latter determines p . The results are reported in Table 8.

Table 8 Cumulative Pass-Through from Exchange Rate to Prices: Impulse Response (p_{t+j}/epe_{t+j})

	June 1994 – June 1998					
	1 month	3 months	6 months	9 months	11 months	12 months
Ordering: m - epe - p	0.06	0.32	0.53	0.78	0.96	1.06

Note: Baseline VAR model is of order 3. Estimated impulse response function uses the Cholesky decomposition of the residual covariance matrix from the corresponding vector equilibrium error correction model. Decomposition follows the pattern of estimated Equations (3) and (4): m is exogenous and affects epe , while e subsequently influences p .

Source: Authors' calculations.

Cumulative ERPT stabilizes at 1, indicating again that long-run pass-through is complete, and therefore supporting the cointegration estimate above. Also, the speed of pass-through has substantially decreased compared to hyperinflation, as it now takes 12 months to reach the long-run value.

3.3 Moderate Inflation in the 2000s: Large Inflow of Capital and Supply Shocks

As suggested in Section 2 above, inflation in the 2000s was driven by the supply side shocks, specifically the increase in wages, and the related rise in food and oil prices, as well as nominal appreciation or depreciation of the currency. On the demand side, large inflow of capital led to overheating of the economy that could be captured with output gap movements.

Therefore, we start with cointegration analysis of four I(1) variables, i.e. logs of the price level (p), the wage rate (w), i.e. the price of the main non-tradable, the exchange rate (epe) being the price of tradables, and the price of oil in domestic currency ($poil$). Subsequently, we add stationary output gap (y) in the corresponding equilibrium-correction-model (ECM) for inflation.

The testing, using Johansen (1996) cointegration procedure, shows that the four I(1) variables mentioned cointegrate and that there is only one cointegration vector among them (cf. Table 9).

The corresponding long-run (cointegrated) price equation, a version of long-run aggregate supply, reads as follows:

$$p = 0.21epe + 0.33w + 0.11poil - 0.50. \quad (5)$$

It suggests that the above proposed supply side factors to determine inflation in the long-run during the 2000s in Serbia. Within this framework, one also acquires estimate of the long-run ERPT, being now equal to 0.21. This represents a substantial

drop in the long-run (cointegration) pass-through estimate from complete i.e. 1 in the 1990s to 0.21 in the 2000s, indicating that structural change did occur.

Table 9 Cointegration among the Price Level (p), Exchange Rate (epe), Wage Rate (w) and Price of Oil ($poil$)

July 2001- July 2008							
Rank	Eigenvalue	Trace test	Cointegrated vector				
$r=0$	0.547	72.84	p_t	epe_t	w_t	$poil_t$	1
$r\leq 1$	0.082	7.08	1	-0.205	-0.329	-0.111	0.498

Note: Cointegration analysis is performed within a partial VAR model such that wages and oil prices are treated as weakly exogenous variables. Weak exogeneity of these two variables is detected in the first step of the cointegration analysis when an ordinary VAR model is used. A constant term enters the VAR model unrestrictedly. There are two lags in the model. The estimated VAR model contains eight dummy variables. Five of them take non-zero value 1 for the following months: 2002:7, 2004:12, 2005:12, 2006:7 and 2006:10,11, while three of them capture transitory blips, such that they take non-zero values 1/ -1 for the following months: 2007:3/4; 2007:10/11 and values -1/ 1 for 2008:4/ 5. The 5% critical values for the trace test are simulated using CATS in RATS to account for presence of dummy variables (Dennis 2006). The critical values are: 28.805 ($r=0$) and 14.35 ($r\leq 1$).

Source: Authors' calculations.

As a side result, it is obtained that the pass-through from international fuel prices ($poil$) to domestic prices was 0.11 which is almost equal to the estimate obtained for emerging economies for the 1995-2008 period.⁸ Thus, Serbia in the 2000s also exhibited low pass-through from energy prices into domestic price level, joining the global trend of decreasing impact of these prices on domestic inflation as observed in the last two decades in both developed and emerging economies (cf. International Monetary Fund 2008, Figure 3.11, p. 107; and Mishkin 2008).

The ECM for inflation (6), corresponding to cointegrated relation (5), does suggest that the effect of output gap (y) on inflation was significant, hence confirming the importance of aggregate demand as an inflation driver in the 2000s.

$$\Delta p_t = -0.07(p_{t-1} - 0.21e_{t-1} - 0.33w_{t-1} - 0.11poil_{t-1} + 0.50)_{t-1} + 0.02\Delta w_t + 0.13\Delta e_{t-2} + 0.04y_{t-3} + residual$$

(-13.53) (3.60) (2.95) (2.02)

$$\bar{R}^2 = 0.57, Q(6)=2.58(0.86), Q(12)=7.82(0.88), JB=0.55(0.76), WH=11.78(0.55).$$

Sample: April 2002 – July 2008.

(6)

Note: t -ratios are in brackets. In addition, the model contains three significant impulse dummy variables that take non-zero value 1 for the following months respectively: July and October 2002, and January 2005 (VAT). p -values of the Box-Ljung (Q) autocorrelation test of order 6 and 12, the Jarque-Bera (JB) normality test and the White heteroskedasticity test (WH) are in brackets.

Cumulative ERPT coefficients will be assessed by estimating VAR model first just with the levels of four I(1) variables that are cointegrated: p , epe , w and $poil$, i.e. without I(0) output gap. Subsequently, the first difference of the four I(1) variables will be combined with the output gap, thus estimating another VAR model with variables that all are stationary.⁹

⁸ Cf. International Monetary Fund (2008), Chapter 3, Figure 3.11, p. 107.

⁹ As in this case, the estimated vector equilibrium correction model is partial, we do not use its impulse response functions. Nevertheless, even the employed unrestricted VAR model provides reliable estimates

Cumulative pass-through coefficients, acquired from the VAR model containing the four I(1), are reported in Table 10.

Table 10 Cumulative Pass-Through from Exchange Rate to Prices: Impulse Response (p_{t+j}/epe_{t+j})

July 2001 – July 2008							
Ordering	3 months	6 months	9 months	12 months	18 months	24 months	36 months
<i>poil-w-epe-p</i>	0.21	0.26	0.30	0.33	0.38	0.41	0.47
<i>poil-w-p-epe</i>	0.15	0.20	0.25	0.28	0.34	0.38	0.44

Note: Estimates are derived from VAR model of order 3 that contains four impulse dummy variables (that take only non-zero value 1 for: 2002:7, 2003:4, 2005:1 and 2006:7 respectively) and seasonal dummy variable for December. Impulse response function is based on the Cholesky decomposition of the residual covariance matrix for two different orderings. First ordering assumes exogenous nature of oil prices that affect wages, while both of them influence exchange rate. At the end, prices are being affected by all three variables. In the second, ordering roles of prices and exchange rate are switched.

Source: Authors' calculations.

Another specification that also includes the output gap, hence capturing the demand side shocks, gives similar estimates of cumulative ERPT (cf. Table 11).

Table 11 Cumulative Pass-Through from Exchange Rate to Prices: Impulse Response (p_{t+j}/epe_{t+j})

January 2002 – July 2008					
Ordering	3 months	6 months	12 months	24 months	36 months
$\Delta poil-y-\Delta w-\Delta epe-\Delta p$	0.15	0.25	0.30	0.34	0.36

Note: Estimates are derived from VAR model of order 3 that contains four impulse dummy variables (that take only non-zero value 1 for: 2002:7, 2003:4, 2005:1 and 2006:7 respectively) and seasonal dummy variables for December and January. Impulse response function is based on the Cholesky decomposition of the residual covariance matrix for the following ordering: the first difference of log oil prices-output gap-the first difference of log exchange rate-the first difference of log prices.

Source: Authors' calculations.

Both sets of ERPT estimates show that the long-run pass-through was incomplete, i.e. less than 1, and low. These long-run ERPT estimates were however somewhat higher than the one obtained from cointegration analysis (0.21). As to the speed of ERPT, it was slow, i.e. it took it 36 months to achieve stable long-run value. Alternatively, the short-run ERPT coefficients were very low, being hardly 1/3 even for one year. All of the above indicates that a structural shift occurred in the 2000s even when compared to the high inflation in the 1990s.

4. Explaining Variations in ERPT across Inflation Episodes: Role of Price Rigidities

We shall now bring together pass-through estimates across diverse inflation regimes and show that they co-move with inflation levels, volatility and persistence respectively, as well as with that of currency depreciation.

The level, variability and persistence of inflation and currency depreciation changed substantially over the analyzed episodes in Serbia (cf. Table 1 and 2 above)

of impulse response functions as the previously used restricted cointegrated VAR one does (Atsuyuki Naka and David Tufte 1997).

lending opportunity to explore their effect on pass-through (e.g. Taylor 2000; Gagnon and Ihrig 2004; Choudhri and Hakura 2006). From the extreme hyperinflation of 1992-93, inflation descended in two steps: to high inflation later in the '90s and a moderate one in the 2000s. The variability (i.e. standard deviation) of inflation and its persistence evolved in the same manner. The same pattern was largely followed by currency depreciation (cf. Table 1 and 2).

Summary of ERPT estimates across inflation episodes given in Table 12, as well as the more extensive review reported in Section 3 above, do show that the size and speed of ERPT co-moves with the level and variability of inflation and currency depreciation, respectively.

Table 12 Exchange Rate Pass-Through into Prices

	Cumulative: impulse response ($\rho_{t+j}/\epsilon_{t+j}$)					Cointegration
	1 month	3 months	6 months	12 months	Long-run	Long-run
Hyperinflation 1992-93	0.23	0.90			1 (3.5 months)	1
High inflation 1994-98	0.04	0.32	0.53	1.06	1 (11.5 months)	1
Moderate inflation in the 2000s		0.15	0.25	0.30	0.36 (36 months)	0.21

Source: Authors' calculations.

Thus, the result obtained in panel studies for industrial countries (Gagnon and Ihrig 2004), and jointly for developed and developing countries (Choudhri and Hakura 2006; and Devereux and Yetman 2010), is born out in a single small open developing economy across diverse inflation regimes. As to the persistence, the results for Serbia parallel those for the US, where pass-through also declined with a decrease in inflation persistence (cf. Taylor 2000), thus supporting the hypothesis that the latter influences the former.

The speed of ERPT increases with inflation: to reach the long-run value it takes 36, 11.5 and 3.5 months respectively as one moves from moderate to high and finally to hyperinflation (see Table 12). Alternatively, in the short-run, e.g. for three months, the majority of price adjustment to exchange rate shock takes place in hyperinflation (90%), then in high inflation (32%), while in the moderate one the adjustment is just half of the latter (15%). Moreover, in a year's time, ERPT in moderate inflation is less than one third of that in high inflation (see Table 12). These variations in size and speed of ERPT might be accounted for by an increase in price flexibility with inflation.

To that end we shall use indirect evidence, i.e. refer to surging empirical research on state contingent behavior of pricing, indicating a sharp increase in frequency of price adjustment during high inflation and large devaluations (cf. Gagnon 2009; Alvarez et al. 2013; Burstein and Gopinath 2013). Thus, in high inflation, when price adjustments are more frequent, shock in exchange rate would spill-over into prices faster, thus accounting for the results reported above.

Specifically, empirical evidence on frequency of price adjustments across inflation episodes ranging from low inflation to hyperinflation in Argentina (Alvarez et al. 2013), is complementary to our findings for ERPT behavior across similar inflation episodes. Additional evidence for low to high inflation periods for a number of

episodes¹⁰ conforms to the pattern found in the overlapping Argentine's episodes.¹¹ This lends additional credibility to the corresponding evidence for very high and hyperinflation although the latter refers only to Argentina, suggesting that the findings on state contingent price setting might bear general relevance.

The common pattern observed indicates that in low to moderate inflation, i.e. between zero and 10 to 15% per annum, frequency of price changes is constant, while above the latter threshold, an increase in inflation is associated with a rising pace of price adjustments (cf. Gagnon 2009; Alvarez et al. 2013). Thus, the moderate inflation episode in Serbia (cf. Table 1) conforms to the range where variations in inflation do not trigger changes in frequency of price adjustments, hence indicating once again that this episode is distinct from the high and hyperinflation ones. On the other hand, both high and hyperinflation episodes in Serbia belong to those where rising inflation generates increasing price flexibility.

Menu cost models can account for the observed co-movement of inflation and frequency of price changes in Mexico (Gagnon 2009) and Argentina (Alvarez et al. 2013) thus rendering general bearing to this relation. Intuitively, for a given cost of price changes (e.g. menu cost), inflation rise causes an increase in frequency of price changes, as with higher inflation it becomes more costly for firms to keep prices unchanged than to change them.

Combining the findings across moderate, high and hyperinflation for ERPT in Serbia, with the corresponding ones on frequency of price changes in Argentina, one finds empirical support for the hypothesis that the degree of price rigidities determines the size and speed of ERPT (cf. Engel 2002; Choudhri, Faruquee, and Hakura 2005; and Devereux and Yetman 2010).

Devereux and Yetman (2010) also offer empirical support for our findings above that a rise in inflation generates an increase in the frequency of price changes, while the latter leads to higher ERPT. The result is obtained for a panel of low and high inflation countries, hence complementing our findings for one country albeit across an extreme range of inflation experience. Additional empirical evidence on a positive relation between the frequency of price changes and the size of ERPT is found in a different set-up, i.e. across commodities, showing that higher-frequency adjusters have significantly higher ERPT (Gopinath and Itskhoki 2010).

5. Conclusions

We have found that the size and the speed of ERPT drops as inflation descends across episodes of extreme hyperinflation via high inflation to a moderate one, in a single country - Serbia. Specifically, we found that ERPT decreases with a decline in the inflation level, variability and persistence. These results complement those previously acquired in panel studies across both developed and developing economies.

The observed fall in ERPT can be explained by changing price flexibility across the analyzed inflation episodes, thus pointing to the degree of price rigidity as

¹⁰ For a review see Gagnon (2009), Table IV, p. 1245, and Alvarez et al. (2013), Table 13, p. 59 and Figure 20, p. 58.

¹¹ Cf. Alvarez et al. (2013), Figure 20, p. 58.

a key determinant of the size and speed of ERPT (cf. also Engel 2002; Choudhri, Faruqee, and Hakura 2005; and Devereux and Yetman 2010). Namely, complementary empirical evidence across similar inflation episodes in Argentine shows that the frequency of price adjustment substantially increases as it moves from low to hyperinflation (cf. Alvarez et al. 2013). This state contingent behavior of pricing is also found in a number of low to high inflation episodes (see Gagnon 2009), and observed co-movement of inflation and frequency of price adjustment can be explained by menu cost models. All this renders general bearing to this result, suggesting that it may also hold for the Serbian inflation episodes.

ERPT estimates are embedded in careful analysis of the inflation episodes in Serbia, showing that the hyper and high inflation in the 1990s subscribe to the same fiscal explanation as opposed to the moderate inflation episode of the 2000s, where supply and demand shocks were the main inflation drivers. In the former case, an in-depth cointegration analysis shows that money supply is the stochastic trend that drives currency depreciation and inflation, while monetizing fiscal deficit. The exchange rate, both in the hyper and high inflation episodes, is determined outright by its sole fundamental i.e. money supply, while due to high dollarization currency depreciation subsequently sets inflation. The latter led to observed complete ERPT in the long-run, both in the hyper and high inflation episodes.

Monetization of fiscal deficit was halted at the beginning of the 2000s, indicating a policy regime change in Serbia, and laying a foundation for moderate to low inflation. As in other emerging European economies, food and oil price shocks as well as large inflow of capital and the consequent overheating of economy triggered moderate inflation in Serbia, leading to slow and modest ERPT. Cointegration analysis, that took into account the supply side shocks, gave incomplete and moderate long-run ERPT estimate (0.21), similar to the cumulative long-run estimate of ERPT from a VAR model that also captured the demand side shocks (0.36). Moreover, ERPT became much slower in the moderate inflation episode as it takes 36 months to reach the long-run value compared to only 14 and 3.5 months in the high and hyperinflation episode respectively. Thus, findings for Serbia in the 2000s concur with new empirical evidence showing that pass-through has significantly declined, even in developing open economies (cf. Frankel, Parsley, and Wei 2005), and our findings support the view that a low inflation environment, and policies leading to it, are critical.

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