

## **Abstract**

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## **SECTION 1. INTRODUCTION**

## SECTION 2. LITERATURE REVIEW

The goal of pioneering works in exchange rate pass through estimation area was mainly in determining industry-specific effects in specific economies: among others, (Schembri 1985) examines Canadian exports, (Menon 1992; Menon 1993) — Australian exports and Imports of Motor Vehicles, (Khosla 1991; Athukorala, Menon 1994) — Japanese exports, (Cowling [et al.] 1989 — UK and West German car market, Athukorala 1991 — Korean exports, Baldwin 1988; Feenstra 1989; Hooper [et al.] 1989) — US imports. These papers show that there is a heterogeneity in pass-through across industries as well as countries though challenging data measurement errors and model misspecifications. A huge contribution to review these attempts is made in (Menon 1993; Menon 1995).

Looking for exchange rate pass-through for whole economies, (Khosla, Teranishi 1989) estimate shock-independent ERPT to export prices for 23 countries using calculated quarterly nominal effective exchange rate for each economy and fitting OLS regressions. They find that pass-through effect varies drastically across countries: for developed economies this value is high, meanwhile developing ones experience low pass-through.

A more advanced methods are used in (Y. Kim 1990) — author examines pass-through to US import prices and influence of exchange rate to mark-up using a model with time-varying parameters. It is shown that a mark-up negatively correlates with US dollar exchange rate, though a direct effect of the latter to prices fell from 1980s.

In (Deravi [et al.] 1995) a vector autoregression (VAR) is applied to fit US broad money aggregate, dollar exchange rate and consumer price index (CPI) with a main emphasis on monetary supply shock. Via causality test It is underlined that there is a significant causality effect of broad money to other macrovariables. Variance analysis suggests the effects to CPI from innovations to other two variables are nearly equal after four years.

(K.-H. Kim 1998) employs vector error-correction model (VECM) in order to study pass-through to US import prices. This paper reveals a significant negative effect of US exchange rate appreciation to producer price index (PPI) and conducts causality test for this dependency, which confirms an influence of exchange rate. Moreover, author argues that previous works were using inefficient methods to examine ERPT.

In his renown paper, Taylor (2000) provides strong theoretical framework for understanding exchange rate pass-through nature. The author simulates three-equation model of individual and aggregate prices and output and shows that when the inflation is low, pricing

power of firms declines as well leading to lower pass-through. Hence, if a producer wants to raise or lower their individual price due to change in costs or, equivalently, exchange rate, he or she would expect other firms stay on the remaining price level due to low inflation.

Another approach of examining exchange rate pass-through is contained in literature based on general equilibrium models, although there are few ones specially structured for studies in this particular field. Mainly based on purely statistical approach, this particular paper refers only to several works of this kind, leaving the rest to the reader.

One of the works is Adolfson 2001, where author examines optimal policy of monetary authority under different completeness of pass-through. The main consequence of this study is that the lower pass-through is, the less important nominal economy is, as interest rate response to shocks from outside is lower and exchange rate fluctuations are higher.

The seminal paper in this field is Obstfeld [et al.] 2002. It does not directly touch the pass-through problem, however, it is a starting point for many papers in this field. In the paper, a cooperation of monetary authorities in a two-country model is examined. The main result of this paper is that even if monetary authorities do not coordinate with each other, benefits from macroeconomic stabilization can outweigh lack of coordination, and coordination under fixed exchange rate is more preferred than one under the floating rate.

Looking for effects of exchange rate volatility, (Devereux [et al.] 2002) develop a multi-economy new-Keynesian general equilibrium model based on the model from aforementioned paper. Authors show that fluctuations in nominal exchange rate appear to compensate pass-through to prices nominated in local currencies. It is argued that even if there is a little volatility in fundamental macroeconomic variables, fluctuations of exchange rate may be quite high. This model lacks empirical research though, constrained only by simulations with different parametrisation.

Basing on the same foundations, an attempt to make an empirical research based on DSGE model is done in (Smets [et al.] 2002), where Euro area data is used to calibrate a model and estimate exchange rate pass-through in an economy with optimal monetary policy. As a result, authors claim that under an assumption of presence of import price stickiness in the economy, its effect is similar as stickiness of domestic prices.

Gagnon [et al.] (2004) use Monte-Carlo approach with multi-equation model to show that there was a decline in exchange rate pass-through since 80s due to inflation stabilisation policy conducted by many central banks across the world. To find more evidence, authors fit

an OLS regression with lags of exchange rate summed with foreign CPI for two subsamples individually chosen for 20 countries. Additionally, they estimate interest rate rule coefficients in order to find changes in monetary policy. Finally, authors argue that the hypothesis is confirmed.

A new wave in studying exchange rate pass-through — use of structural vector autoregressions (SVAR) — starts from (Hahn 2003) for Euro area macro data from 1971 to 2002. In this remarkable work, a recursive (also known as *Cholesky*) identification scheme is used in order to recover macroeconomic shocks to PPI and HICP from other different macroeconomic variables (oil price, interest rate, output gap and non-oil import prices). To address statement about pass-through decline in (Gagnon [et al.] 2004), author conducts a robustness test and finds out that there was no significant change in pass-through effect for the Euro area.

The same conclusion about decline, among other ones, is made in (Campa [et al.] 2005). Searching for the pass-through effect to import prices, authors examine data for 23 countries and assert that the pass-through effect is incomplete for all countries in the short run and for overwhelming majority of them in the long run.

(Ca' Zorzi [et al.] 2007) and (McCarthy 2007) papers resemble previously cited (Hahn 2003). The first work studies data for 12 developing economies and employs recursive SVAR to estimate shock-dependent ERPT; authors find that pass-through effect fades down to the distribution chain and argue that when inflation in a developing economy is low, ERPT is comparable to one of developed countries.

On the opposite side is (McCarthy 2007) work, where data for nine developed countries are examined applying Cholesky identification scheme to VAR. Author states that pass-through in developed economies is quite low, and inflation in the US is mainly driven by oil shocks, producer price shocks and internal CPI shocks.

In (Shambaugh 2008) paper author uses long run restrictions for SVAR in order to identify link between exchange rate and CPI together with import prices. Author uses data for 16 countries for the time frame from 1973 to 1999 and obtains supportive evidence that low inflation declines pass-through — for some countries, CPI growth rate does not respond to exchange rate shocks in the same magnitude as producer price index growth rate.

Data's granularity higher than quarterly is not usually found in the studies, although (Amstad [et al.] 2010) observe monthly Swiss CPI and NEER from 1993 to 2008. This

work employs event study approach to estimate an effect of monthly import price time series release to ERPT. Author underlines that this method is more suitable for policymakers due to possibility of using the most current data and does not rely on VAR restrictions, which may be controversial. The criticism of SVAR is quite questionable in this light, since the monthly data does not impair a possibility of proper identification of shocks, while the benefits of shock-dependent ERPT are higher for monetary and macroprudential authorities.

An innovative identification method is introduced by An, Wang (2012) — author employs sign identification scheme in order to obtain price-to-exchange rate ratio (*PERR*, shock-dependent exchange rate pass-through), which will be described in the following Section. Author fits the model for eight developed economies and claims that for the most cases pass-through is incomplete. Another conclusion is that pass-through is higher for small-sized economies with more volatile monetary policy.

The work of Delatte [et al.] (2012) is devoted to determination of pass-through asymmetry for four countries (Germany, Japan, UK, US) from 1980 to 2009. An ARDL with nominal exchange rate changes divided into two variables (with positive and negative increments) is estimated to determine both short-run and long-run asymmetric ERPT. Author argues that pass-through is smaller during local currency appreciations.

(Brun-Aguerre [et al.] 2012) paper's aim is to find what drives ERPT to import prices. Authors use both ECM and panel fixed effects (FE) model to catch time- and country-specific effects for 37 countries on 1980–2009 period; again, pass-through asymmetry is considered. The conclusion is that there is no evidence of pass-through declining for both developed and emerging economies, although domestic tariffs and import-to-export ratio matter.

Monthly data of Taiwanese economy under deflation are examined in (Lin [et al.] 2012). In this work, a two- and three-regime threshold autoregression (TAR) models are fit to find non-linearities in pass-through relation. It is argued that pass-through declines only when inflation is close to zero, and the link of ERPT and inflation is V-shaped. With this non-trivial result, high rates of deflation are unpleasant for an economy additionally from the side of exchange rate pass-through.

Another work observing Asian economy is (Jiang [et al.] 2013). Authors estimate SVARs with custom shock matrix in order to find *PERR* for China. This method is more flexible than recursive identification scheme as the shock matrix does not necessarily need to be triangular, although application of such scheme is quite situational. Authors conclude that *PERRs* are

incomplete, which is usual for the literature in this field.

(Yamada 2013) paper is devoted to study exchange rate regime effect to inflation among developing and emerging economies. Author fit treatment effects model with propensity score matching based on GDP and geographical characteristics in order to calculate between inflation targeting regime and other ones. The conclusion is that inflation targeting exchange rate regime performs at least not worse than fixed regime in terms of inflation lowering.

Multi-currency study for 17 countries of Euro area is done by Bandt [et al.] (2014) to estimate effect of exchange rate fluctuations to import prices for multiple trade partners. Currencies chosen are US dollar, UK pound-sterling and Chinese Renminbi. Authors estimate FE model in order to calculate ERPT and find out that in the short run pass-through is incomplete, but its completeness is confirmed for the long run.

In order to look for the changes in pass-through after 2008 financial crisis, Jasova [et al.] (2016) estimate 6-year rolling ERPT for both developing (11) and advanced (22 countries) economies completing their study by fitting two-way FE model. Authors assert that pass-through declined during financial crisis for developing economies, meanwhile ERPT of developed countries remained on a relatively stable level.

In (D. Comunale M. K. 2017) paper data for four Euro area countries — France, Germany, Italy and Spain — are studied to find both ERPT and PERR under the zero lower bound (ZLB) environment. Instead of short-term interest rate, authors make use of calculated *shadow interest rates* and estimate Bayesian VAR with sign and zero restrictions. The results of the study are that pass-through is high and volatile to import prices and, in general, is dependent on shocks evolving. Moreover, authors state that the process of choosing identification scheme is quite sophisticated, and the identified shocks are true only conditional on the scheme involved.

Both FE model and sign and zero restricted SVAR are estimated in (K. J. Forbes [et al.] 2017), where authors try to analyse time- and country-specific differences in pass-through on the sample of 26 countries. It is argued that structural variables, like the first two statistical moments of inflation and exchange rate are important for time and country effect explanation, while structural shocks are crucial for explanation of macro-variable variation in time.

A quite remarkable paper of the same collective is (K. Forbes [et al.] 2018). Authors study UK economy pass-through before and during Brexit using SVAR model with sign and zero restrictions. The study shows that pound-sterling's depreciation periods during 2008



financial crisis and Brexit have different ground and discrepancy in inflation rates are caused by different shocks affecting the economy. Authors admit that set up in this fashion, a model cannot capture all the complexity of pass-through nature, although identification of shocks can help to improve relevant policy by monetary authority.

Another work employing the same method is (An, Wynne, [et al.] 2020), though *narrative* sign restrictions (simply put, signs dictated by historical events) are added. The main drivers of Japanese pass-through are examined in this study. Authors argue that narrative sign approach is more promising in terms of shock identification procedure.

Time-varying ERPT is examined in (Leiva-Leon [et al.] 2019), where authors estimate time-varying parameters (TVP) dynamic factor model and SVAR with sign restrictions for Euro area. A TVP approach is quite innovative in pass-through literature, as it is highly likely to solve problems of non-linear ERPT estimation. The paper's conclusion is that inflation is mostly driven by exogenous exchange rate shocks, though core inflation are less exposed to these fluctuations.

Colavecchio [et al.] (2019) use local projection method in order to capture non-linear pass-through effects for the 19 countries in Euro area. Plainly speaking, local projections are *h*-ahead forecasts on the basis of current data. The results show that there is no complete pass-through for all the countries neither after a one year nor two years. Authors also find there is a sign and exchange rate shock size non-linearity for some countries.

The recent work of M. Comunale (2020) is devoted to a comparison of Bayesian SVARs and DSGEs for the purposes of PERR estimation. This particular work is important in the sense that SVAR and DSGE models can give controversial results; hence, a policymaker needs to distinguish an appropriate aims for both setups. Author finds out that just after a shock PERR's are identical for both models, although in the long-run estimates from DSGE are higher due to endogenous response of macrovariables.

DSGE is also employed in (García-Cicco [et al.] 11/2020), where comparison of shock-independent ERPT's and PERR's is done on Chilean data. It is argued throughout the work that pass-through conditional on shocks gives a full picture of macroeconomic variables' relations and that DSGE models are helpful to generate prudent monetary policy.

In their latest work, K. Forbes [et al.] (2020) estimate both SVAR and FE model for a set of 26 countries in order to review "*shocks vs. structure*" dilemma. Authors claim that both structural characteristics and shocks are important for better understanding pass-through.

Also they find an evidence that monetary shocks are associated with large PERR, which made a big contribution to price fluctuations in advanced economies that are not close to the lower bound.

All in all, there has been a shift in the literature from industry-specific studies to understanding of shock importance during exchange rate pass-through estimation. This drift is dictated not only by an evolution of methodology (this point is prevalent though), but data availability and, what is the most important, a switch to macroprudential policy. The intervention of vector autoregressions and Bayesian estimation techniques, especially sign restrictions, have given, in some sense, the second breath to the research. On the other hand, further development of DSGE models and acceptance of them by central banks globally gave an idea of how shock-dependent ERPT should look like for each country. The idea of SVAR being guided by DSGE (at least for a signs) is given in (Ortega [et al.] 2020), which is a brilliant review on the topic of exchange rate pass-through estimation with a focus on Euro area and the US.

### **Russia and CIS**

One of the first works exploring the Commonwealth of Independent States (CIS) is (Korhonen [et al.] 2006), where authors estimate VAR models for each country-member using the data from 1999 to 2004. This work is quite disputable as, for instance, Russia and Kazakhstan have *negative* ERPT, which is highly unlikely even considering the policy in 2000–2005. On the example of Russia, the most obvious omission in this study is that the model is fitted on the data after 1998 default, which led to huge surge in exchange rate due to risk premium shock. After this event, it seems that the ruble was underappreciated, and its exchange rate was lowering from 2000 till 2008 financial crisis together with rise in oil price. Being fitted with this data, VAR may generate biased results, as effects from several shocks are not taken into account: the influence of risk premium shock was declining together with rising oil price shock. Due to this issue, the cited work is a good example why shock-dependent ERPT is important for proper policy implications.

Oomes [et al.] (2005) study the relation of inflation and money demand on the example of Russia in 1996–2004. The main focus of this work is economy dollarisation — the influence of foreign currency holdings in the country. As a side effect, authors estimate ERPT to control for influence of money aggregate to inflation.

DSGE model for Russia and China is presented in (Sosunov [et al.] 2006), where a response of exchange rate to foreign currency accumulation policy by central bank is studied. Analysis shows that low level of money in the economy for Russia in 2001–2005 is a pro-inflammatory factor. Moreover, it is underlined that the management of real exchange rate by means of currency accumulation has a little effect to it.

The model for Russia in Dobrynskaya [et al.] 2008 is fitted on the sample from 1995 to 2002. This work employs two single-equation regressions (simple and extended ones) in order to estimate ERPT for the country. The choice of time-frame and model (OLS) there is questionable, since the surge of CPI and exchange rate after 1998 crisis probably lead to unreliable estimates, although results in the paper do not contradict economic intuition. Authors argue that exchange rate pass-through in Russia is fast, as a huge part of it comes into inflation right in one month after exchange rate shock.

In (Kataranova 2010), a more recent (2000–2008) data are used. Author fits different specifications of OLS models accounting for asymmetry in order to evaluate ERPT. The results are that the presence of pass-through asymmetry is confirmed for Russia, and the effect of ruble decline caused by 2008 financial crisis, indeed, was only partial, since the following ruble appreciation strengthen credibility of the local currency.

Beckmann [et al.] (2013) estimate exchange rate pass-through for CIS countries on the data from 1999 to 2010. Authors obtain negative ERPT estimate from VAR model for USD-RUB pair and the same estimate close to zero for EUR-RUB pair, which contradicts reality. Authors address this issue by pointing out that this pass-through estimate is shock-independent and there is an uncontrolled effect of oil shocks.

In (O. Faryna 2016a) paper author estimate bilateral panel VAR for both Russia and Ukraine to study cross-country spillovers. Author claims that depreciation of ruble causes increase in Ukrainian inflation, which follows intuition as Russian and Ukrainian economies have been quite integrated (even after 2014 political crisis this degree of integration remains high). Moreover, it is observed in this paper that inflation in Ukraine responds to USD-RUB changes higher than to USD-UAH (Ukrainian hryvna — the Ukrainian local currency).

The other work of the same author is (O. Faryna 2016b) examines non-linear ERPT for Ukraine exclusively on the 2007–2016 data. As it is occurred in the literature for Russia, local currency depreciation causes more effect to inflation than its appreciation, although pass-through is higher for Ukraine.

The latest work of H. Faryna O. S. (2018) studies some CIS countries, including Ukraine and, partially, Russia. This paper employs Global VAR model (VAR with equations for each country) fitted on the 2001–2016 data. This model shows a close relationship of Euro area output and output of CIS countries. An oil shocks is definitely positive for Russia, and what is more interesting, it is positive for CIS countries due to spillover effect.

A VECM model with ERPT asymmetry is used in (Ponomarev [et al.] 2016) for 2000–2012 data. Authors break time series into two sub-periods: before and after 2008 financial crisis, to achieve robustness of results. Their findings are that pass-through effect reveals fully in 6-12 month period, and this effect is incomplete.

(M. Comunale, Simola (2018)) estimate fixed effects panel data model with ERPT asymmetry for CIS countries on a 1999–2014 time-frame. Authors claim that pass-through is high for CIS countries, reaching its maximal level in one year. Moreover, they argue that there is a little evidence of asymmetric pass-through, although it doesn't apply to Russia, as this country is just partially included in the study.

In Sinyakov [et al.] 2019 authors calibrate a simplified multi-equation static model of small open economy in order to evaluate industry-specific asymmetry of ERPT. Their findings are that electrical appliance manufacturers and paper producers are less likely to transfer costs from exchange rate fluctuations directly to the final good prices keeping ERPT in this area low. On the opposite, textile and wholesale trading industries have very high pass-through (around 0.5–0.6). The final conclusion is that when produces are aware of competitors' actions in a specific industry, the pass-through is high.

A comprehensive research is done by Khotulev (2020). In this paper, author evaluate both ERPT by means of OLS model and PERR using the Bank of Russia's DSGE model. There are five exogenous shocks in the latter model: oil price, monetary policy, country risk premium, government expenditures and reserves. A quite disputable result is that there is a huge negative PERR due to government spendings shock (-1.596), which may be a result of purely technical restrictions (first-order approximation of DSGE equations).

The evolution of pass-through literature concerning Russia and CIS is fairly limited, since the last work calculates shock-dependent ERPT. Some works include negative shock-independent ERPT for Russia, which is rather dubious for Russian structure of external trade. Table 1 summarizes shock-independent pass-through estimates across the literature.

Paper	Currency	Data	Infl. aggr.	Length	ERPT
Oomes [et al.] 2005	NEER	1996–2004	CPI	Short-run	0.4–0.5
Korhonen [et al.] 2006	USD	1999–2004	ULC <sup>1</sup>	Long-run	-0.42
Dobrynskaya [et al.] 2008	NEER	1995–2002	CPI	Long-run	0.35
Kataranova 2010	USD	2000–2008	CPI	Short-run	0.6–0.20
Beckmann [et al.] 2013	USD	1999–2010	CPI	Long-run	-0.17
Ponomarev [et al.] 2016	NEER	2000–2012	CPI	Short-run	0.046
O. Faryna 2016a	USD	2000–2015	CPI Core	Long-run	0.1
Sinyakov [et al.] 2019	NEER	(2016–2017)	CPI	Long-run	0.35
Khotulev 2020	NEER	2005–2019	CPI	Long-run	0.16

Table 1: Earlier shock-independent ERPT estimates for Russia.

### **SECTION 3. METHODS**

### **SECTION 4. DATA**

### **SECTION 5. RESULTS**

## **DISCUSSION**

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## **Appendix A:**