International Journal of Management, Accounting and Economics
Vol. 8, No. 11, November, 2021
ISSN 2383-2126 (Online)

www.ijmae.com

Original Research

Exchange Rate Pass-Through and Central Bank Credibility: Evidence on Inflation Targeting Countries[1]

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Abstract

This paper sheds a new light on the role of central bank credibility (CBC) in explaining the extent of exchange rate pass-through (ERPT) in two stages. In the first stage, using 60 months rolling window regression of the inflation on the nominal effective exchange rate is obtained time-varying ERPT during 1990m1-2020m1. Once the credibility index (deviation of average of past inflation from target) is computed over a period of 29 years (1991-2019), in the second stage, the sample of 19 inflation targeting (IT) economies are split into different regimes with regard to the credibility values by using a Panel Threshold Regression (PTR) model. Our empirical result shows that there is one threshold point for CBC which is well identified by the data, allowing me to split my sample into two credibility regimes. When CBC level is below a threshold of 35% within a high-inflation environment, the extent of the ERPT coefficient is found to be higher. However, with the shift towards high-credibility regime, when credibility level is exceeding the threshold of 35%, the level of pass-through is significantly declining in the IT countries. This finding sheds further light on how the credibility gained through the commitment to the targets can be effective on the performance of the central bank and would ensure the better control of the pass-through.

Keywords: Central Bank Credibility, Inflation Targeting, Threshold Effect

[1] This paper presented in the Ph.D. seminar in Laboratoire d'Economie d'Orleans, University of Orleans, Orleans, France, September 2020.
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Vol. 8, No. 11, November, 2021
ISSN 2383-2126 (Online)

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Introduction

Over the past two decades, many central banks have adopted inflation targeting (IT) framework to reach a low and stable inflation. As pointed out by de Mendonça & Tiberto (2017) the ability of the central bank to guide private sector expectations–gain of credibility- is an important tool to keep inflation under the control and mitigate shocks effect on the inflation such as exchange rate pass through (ERPT). It is worth clarifying one point upfront. The definition and measure of credibility have been two main challenges in the literature of monetary economics. To address the first challenge and according to the theoretical work of Cukierman & Meltzer (1986), central bank credibility (CBC) is defined as the "average credibility of announcements", meaning that the absolute value of the difference between the central bank's planned monetary policy and private sector's beliefs about those plans. In other words, a monetary authority is said to be credible if "people believe, it will do what it says" (Blinder, 2000). To be more precise, credibility means people believe that the central bank has the willingness, and also the ability to reach the previously announced inflation target. This success can be reached out by anchoring the private sector's inflation expectations on the target and not over-reaction of people to the target misses (Levieuge, Lucotte, & Ringuedé, 2018). In the case of the latter challenge, three main kinds of credibility yardsticks have been extended in the literature: First, Bomfim and Rudebusch (2000) index. This measure considers the weight the private sector attaches to the inflation target when forming their inflation's expectations. Second, forward looking measure, following from classical definition of credibility, refers to the gap between inflation expectations and the target[1]. The well-known index of Levieuge, Lucotte, & Ringuedé (2018) (LLR index) who define credibility as an inverted-U function of this gap (between 0 and 1) belongs to this category. Advantages of this indicator refer to two main properties: first, it is not based on ad hoc upper and/or lower thresholds. Second, negative and positive deviations of the expected inflation from the target are not considered equivalent in terms of (loss in) credibility (non-linearity). Third, backward looking measure of Neuenkirch & Tillmann (2014) (NT index) where the private sector pays attention to the past performance of central bank in formation of expectations.

As the study of the degree of ERPT is a key important issue to consider inflation dynamics, policymakers must be able to gauge the impact of currency changes on domestic prices to determine the persistence of the inflation pressures, the expected inflation, and also an appropriate monetary policy to deal with them. Successful implementation of a monetary policy presupposes that the central bank is credible in private sectors' view. In this way, they not only have a good understanding of inflation dynamics, but they are also successful in control of expected inflation as this is an important factor in the changing behavior of ERPT. Furthermore, domestic demand of real imports influences on the extent of ERPT (and inversely) and thus contributes to the adjustment or non-adjustment of the real domestic trade balance (Cheikh & Louhichi, 2016). As discussed in Taylor (2000), although the higher the weight of imported goods in the household basket, the greater the degree of the ERPT, improving the monetary

[1] See (De Mendonça; 2007, De Mendonça & de Guimaraese Souza; 2009, and Levieuge, Lucotte, & Ringuedé, 2018)

policy credibility largely declines the level of ERPT as there is less need to worry about exchange rate fluctuations.

To test Taylor (2000) hypothesis many authors such as Ben Cheikh & Louhichi (2016) and Ben Cheikh & Ben Zaiedfound (2020) found out that the degree of ERPT is mostly conditioned by the underlying macroeconomic conditions. In other words, bad macroeconomic conditions such as highly inflation environment lead to much greater and faster levels of pass-through than in the low and stable inflation's environment. One reason is that when credibility is low, the economy is not able to isolate the effect of shocks on the exchange rate. In this case, currency devaluation and the pressure on inflation are more raising, leading the level of ERPT tends to be higher than would otherwise be the case (DeMendonça, 2018). Therefore, policymakers should be aware that the announced policy's targets fully incorporate the non-linear reaction's nature of ERPT. Although mentioned studies have considered the nonlinear impact of inflation environment on the level of ERPT, none of them investigated the asymmetric role of CBC in decreasing the ERPT. To fill this void, this paper contributes to the literature by two outstanding properties: first, using a non-linear credibility index showing that the positive and negative deviation from the target do not have the same impact on the credibility. Second, using a Panel threshold Regression (PTR) model to provide the evidence on the regime-dependence of ERPT with regard to the credibility of 19 IT economies. This is done in two stages. The first stage purpose is to consider the impact of exchange rate changes on the inflation rate to obtain the time-varying ERPT. In the second stage, once credibility index is computed, I obtain threshold values to split our country sample into different regimes by using PTR model. Finally, I estimate the effect of the weight of imported goods on ERPT (Taylor hypotheses) for each credibility regime in order to make a comparison between different groups. To the best of our knowledge, this paper is the first study that applies PTR method in this context. The finding of the first stage confirms that emerging countries such as Romania and Ghana have a higher level of the ERPT than other IT economies. In the second stage, I find one threshold to divide IT economies into two low and high credibility regimes confirming that central banks with lower level of credibility (improper performance in control of inflation) have the higher level of pass-through of exchange rate. The latter is an important source of nonlinearity in ERPT across countries.

The remainder of this paper is organized as follows. Section 2 reviews the literature. Section 3 provides the data and methodology. The results and Robustness check are presented in section 4 and 5 respectively. Section 6 concludes.

Related literature

Unlike some strands of the literature about the degree of ERPT as a central role in international economies (Chou K, 2019) my focus is on a more recent occurrence which whether the ERPT can be influenced by the macroeconomic environment, and in particular, the role of CBC. Taylor (2000), in a very seminal paper, by using a microeconomic model of price setting, explains that the shift towards more credible central bank and thus, a low-inflation regime, would reduce the transmission of changes in exchange rates to the inflation (ERPT). In general, the more credible central bank, the more details provides about how and why policies can meet the target inflation rate. For

this reason, a credible central bank has leeway to deviate from its typical policy settings when atypical conditions (shocks) arise. Thus, the private sector is not doubted that the deviation is temporary and longer-term pursuit of the central bank's target is certain. Not only this assumption is very appealing, but it has received strong empirical supports in the recent literature. Gagnon & Ihrig (2004) provide an evidence on Taylor's theory. Dovern et al. (2012) confirm that a credible monetary policy contributes to anchor inflation expectations and declines the macroeconomic shocks. De Mendonça & Tostes (2015), through an analysis for the Brazilian experience under IT, found that the monetary and fiscal credibility have might been effective in weakening the pass-through. In a comprehensive study covering about 114 developing countries over the period 1990–2013, De Mendonça & Tiberto (2017) provide robust evidence for a negative linear correlation between CBC and the effect of ERPT on inflation volatility. They do this by using S-GMM and forward looking measure of credibility index, presenting that the ERPT is a linear function of the sum of the log of nominal exchange rate (EX) and the log of wholesale price index. Kabundi & Mlachila, (2019) directly test the hypothesis - negative linear relationship between credibility and the level of ERPT- in South Africa during 1980Q1 to 2015Q2 by looking at two stages. The first stage is based on 10-years rolling window regression to obtain the time-varying ERPT. In the second stage, they use a linear credibility index to consider the link between the CBC and ERPT.

In the mentioned studies, in one hand, CBC is a linear index in the sense that the positive and negative deviation from the target has the same impact on CBC. In other hand, they indirectly support Taylor's theory by focusing on the CBC as an explanatory variable. Nevertheless, it is worth noting that many empirical studies gave straight supportive evidence to Taylor's view by focusing on the inflation's environment regime (e.g. Barhoumi, 2006; Cheikh & Louhichi, 2016; Ben Cheikh & Ben Zaiedfound, 2020). As the CBC has an outstanding role to gain the low inflation's environment, this paper not only uses a nonlinear indicator to deal with the linear responses of CBC, but it also implements an alternative methodology of PTR model to split my sample into classes based on the value of CBC levels.

Central Bank Credibility and Existing Measures

Three main types of credibility measures have been extended in the literature. The first measure refers to the Bomfim & Rudebusch (2000) approach which consists of assessing the weight the private sector attaches to the inflation target when forming their inflation expectations. Specifically, they assume that long-run inflation expectations at time t, denoted $\pi^{e}_{\infty|t}$, are a weighted average of the current target $\hat{\pi}_t$ and past inflation rate over α periods ($\bar{\pi}_{t-\alpha} = \pi_{t-1} + \ldots + \pi_{t-\alpha} / \alpha$):

$$\pi^{e}_{\infty|t} = \lambda\hat{\pi}_t + (1-\lambda)\bar{\pi}_{t-\alpha}, \qquad (1)$$

The parameter λ $(0 \le \lambda \le 1)$ measures the central bank credibility. If λ = 0, there is no credibility and the inflation target is ignored in the formation of expectations by economics' agents. On the contrary, If λ = 1, central bank is full credible and private sector's long-run inflation expectations are equal to the announced long-run target of the policymaker. This means that the higher the weight attached by the private sector to the

target, the higher the central bank credibility will be. In this case, expected inflation is equal to the inflation target due to the absence of serial correlation in the shock process, the lack of any backward-looking element in the model equations, and the discretionary nature of monetary policy where the model collapses to the standard case of rational expectations. To sum up, two shortcomings of this approach driven by the following restrictions: first, representing λ as a subjective probability of private's agents to attach the future achievement of the target. In other words, if agents are heterogeneous, λ could be considered the fraction of the population that believes the target will be achieved. Second, considering λ as a time-invariant parameter.

The second type of credibility measure refers to the forward looking version. While all forward looking measures such as Cecchetti & Krause (2002), De Mendonca (2007), De Mendonça & de Guimaraese Souza (2009), and Levieuge, Lucotte, & Ringuedé (2018) take into account the gap between inflation expectations and the inflation target as a credibility index, Levieuge, Lucotte, & Ringuedé (2018) extended previous indicators with two main properties: first, not only credibility index should not be based on ad hoc upper and/or lower thresholds, but it also should freely converge towards its extreme values. Second, a credibility indicator should be non-linear. They argue that negative and positive deviations of the expected inflation from the target should not be considered equivalent in terms of (loss in) credibility. Although any deviation from target is a clear signal that people do not believe in the ability of the central bank to meet the commitment, negative deviation is rarely perceived as a signal which monetary authorities abandon their objective as private agents are aware that the central bank can do even better than the announced target in terms of inflation control. Consequently, negative deviations are less serious than positive deviations. In this line of thought, they suggest a flexible indicator that satisfies this dual challenge based on the asymmetrical loss function by using two cases based on whether the target is a single point or a range.

In the case of single point target (as I use this case in my paper), $\pi^e < \hat{\pi}$ is a loss in credibility even if it is less serious than $\pi^e > \hat{\pi}$. Noting $\hat{\pi}^e$, the deviation between expected inflation (π^e) and the target ($\hat{\pi}$) is defined as the following:

$$CR_{LLR} = \left(1/\exp(\hat{\pi}^e) - \hat{\pi}^e\right) \quad , \qquad (2)$$

According to the literature, $0 \leq CR_{LLR} \leq 1$, with representing that the central bank is full credible if CR_{LLR} =1, and on the contrary, CR_{LLR} =0 cites that the corresponding central bank is not credible at all. However, one shortcoming in the forward looking approach is driven by availability of the limited data of the expected inflation.

The third type of credibility measure refers to the backward looking version of Neuenkirch& Tillmann (2014) where future inflation expectations $\pi^e_{t|T}$ are a weighted sum of the constant inflation target $\hat{\pi}$ (the rational expectations component), a non-rational term $(\bar{\pi}_{t-\alpha} - \hat{\pi})\left|\bar{\pi}_{t-\alpha} - \hat{\pi}\right|$, and with δ being a positive constant as the following:

$$\pi^e_{t|T} = \hat{\pi}_t + \delta(\bar{\pi}_{t-\alpha} - \hat{\pi})\left|\bar{\pi}_{t-\alpha} - \hat{\pi}\right| \quad , \qquad (3)$$

They refer to this term $CR_{NT} = (\bar{\pi}_{t-\alpha} - \hat{\pi})|\bar{\pi}_{t-\alpha} - \hat{\pi}|$ as the CBC index ($-1 \leq CR_{NT} \leq 1$), describing how the average of past deviations $\bar{\pi}_{t-\alpha}$ from the inflation target affect the current level of credibility and expectations of the future inflation. To put it in other words, the credibility index states that how past inflation performance of the central bank can be effective on the building (decay) of the credibility over time.

Application to IT economies

To give further insight into the role of CBC and considering a large database that comprises 1991–2019 annual data for IT countries, we employ an alternative index of CR_{NTLLR} which the expected inflation is replaced by the past performance of the central bank as follows[1]:

$$\pi^{e}_{t|T} = \hat{\pi}_t + \delta\left(1/\exp(\bar{\pi}_{t-\alpha} - \hat{\pi}) - (\bar{\pi}_{t-\alpha} - \hat{\pi})\right), \quad (4)$$

$$CR_{NTLLR} = 1/\exp(\bar{\pi}_{t-\alpha} - \hat{\pi}) - (\bar{\pi}_{t-\alpha} - \hat{\pi}), \quad (5)$$

Data

Table 5 in Appendix provides some details concerning the IT adoption date and exchange rate regimes for the period up to 2020. 19 countries (table 1) are selected with regard to two obvious sources of restrictions: first, the ERPT can only be checked for countries that do not have a fixed exchange rate regime. Second, CBC is computed for countries which adopted an IT framework up to 2010.

As previously mentioned, this paper studies the role of the CBC on the level of ERPT in two stages. In the first stage, for each country, monthly consumer price index over the previous year's period and the nominal effective exchange rate data are gathered from the International Financial Statistics (IFS) to obtain the time-varying ERPT based on 5-year rolling window regression for the period 1990m1 to 2020m1. In the second stage, annual data such as the inflation rate, import to GDP ratio and gross domestic product (GDP) are provided by World Bank Indicators. As the output gap may be considered as a macroeconomic determinant of the ERPT, it is computed by the difference between the annual growth rate of GDP based on constant local currency (aggregates are based on constant 2010 U.S. dollars) and the potential output (Hodrick-Prescott filter).

[1] -Since the expected inflation data is available for the period up to 2013, we suggest an indicator by taking equations (2) and (3) (CR_{LLR} and CR_{NT}) together to use large database over a period that spans 29 years (1991-2019).

International Journal of Management, Accounting and Economics
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ISSN 2383-2126 (Online)

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Table 1. Inflation Performance in Relation to Their Targets, 1991-2019.

Countries	Inflation Rate at Start of Adoption Year	Inflation Range Lower	Upper (%)	Target Ranges (+/-)	Average Deviation from Target (%)	Standard Deviation of Target (%)	Frequency of Target Range Misses (%) Total/Below/Above	Continuity of Target Range Misses(Year) Total/Below/Above
Armenia	2.89	-1.82	9.82	1	-0.14	2.91	78.57/ 50 /28.57	11/7/4
Brazil	4.85	-1.02	10.22	2	1.69	2.81	23.8/ 0 /23.8	5/ 0 /5
Canada	5.62	0.33	3.81	1	-0.15	0.87	17.24/ 13.80 /3.46	5/4/1
Chile	3.33	-0.31	6.41	1	0.12	1.68	38.1/ 19 /19.1	8/4/4
Colombia	10.87	1.56	8.24	1	0.38	1.67	71.42/ 33.33 /38.09	15/7/8
Czech Republic	10.69	-0.79	6.57	1	-0.27	1.84	54.54/ 36.36 /18.18	12/8/4
Georgia	1.72	-2.11	11.21	1	-1.03	3.33	81.81/ 54.54 /27.27	9/6/3
Ghana	10.73	0.10	16.74	2	4.05	4.16	69.23/ 0 / 69.23	9/ 0 /9
Hungary	9.11	-0.94	7.78	1	0.60	2.18	73.68/ 26.31 /47.36	14/5/9
Iceland	6.4	-3.76	8.76	1.5	2.16	3.13	47.36/ 0 /47.36	9/ 0 /9
Mexico	6.38	0.99	4.95	3.25	1.36	0.99	10.52/ 0 /10.52	2/ 0 /2
Norway	3	0.57	4.33	0.25	-0.40	0.94	52.63/ 36.84 /15.79	10/7/3
Philippines	2.72	0.26	7.62	0.5	-0.20	1.84	83.33/ 50 /33.33	15/9/6
Poland	11.59	-0.35	7.25	1	-0.27	1.9	68.18/ 50 /18.18	15/11/4
Romania	9.01	-1.09	7.87	1	0.73	2.24	73.33/ 26.66 /46.66	11/4/7
South Africa	5.33	-0.14	9.14	1.5	0.80	2.32	40/ 10 /30	8/2/6
Sweden	4.72	-0.48	4.48	0.25	-0.64	1.24	66.65/ 55.55 /11.11	18 /15 /3
United Kingdom	4.59	0.26	3.74	0.25	0.17	0.87	50/ 21.42 /28.57	14/6/8
Uruguay	8.11	3.16	6.84	2	2.95	0.92	84/ 0 /84	11 /0 /11
All Countries	5.9	-0.39	6.81	1.01	0.49	1.80	54.41/ 26.38 /28.03	11/ 5.5 /5.5
Emerging Countries[1]	6.95	-0.17	8.61	1.37	0.76	2.19	60.75/ 25.44 /35.31	11/4/7
Advanced Countries[2]	4.86	-0.61	5.02	0.65	0.22	1.41	48.07/27.32 /20.75	11/7/4

Note: Inflation rates and target ranges are from World Bank Indicators and the central banks respectively; other variables are based on author's calculations.

Table 1 reflects the inflation performance in relation to their targets. The analysis is on 19 IT countries and distinguishes between emerging and advanced economies. Table 1 shows that although temporary target misses are unavoidable, frequently and large misses threaten the CBC. The main outcomes are given as follows:

- Advanced countries have typically had inflation rate on average of 5 percent at the start of adoption, while emerging countries have usually had a higher rate around of 7 percent.

[1] -Countries: Armenia, Brazil, Chile, Colombia, Czech Republic, Georgia, Ghana, Hungary, Mexico, Philippines, Poland, Romania, South Africa, Uruguay.
[2] - Countries: Canada, Iceland, Norway, Sweden, United Kingdom.

- To keep average of inflation close to the target, advanced countries' performance have been significantly different from emerging countries. Around 70 percent of advanced countries (Canada, Norway and Sweden) have kept the average of inflation less than the target. While, only 28 percent of emerging countries (Georgia, Philippine and Poland) have hold the actual inflation below the target.

- Average of standard deviation of the target in the total sample and emerging countries is only 1.80 percent and 2.19 percent respectively, while dispersion of inflation around the target is significantly high and around 4 percent for Ghana.

- Although both groups have missed their targets almost 11 years, the misses by emerging countries have been around 60 percent of the time and biased upward, while those of advanced countries have missed their targets around 50 percent of the time and biased downward. It is valuable to notice that Brazil, Ghana, Mexico and Uruguay (emerging countries) and Iceland (advanced country) missed their target totally upward.

As discussed in Albagli and Schmidt-Hebbel (2004) and Scott Roger (2009), the policy credibility has an important effect on the volatility of the inflation around the target. The higher frequency, magnitude, and persistence of the target misses during start of the adoption date are likely in part to reflect relatively fragile policy credibility during the early stages of IT. They all find that with weak credibility, the output-inflation trade-off and movements in exchange rates would be also worse.

Methodology

First Stage: ERPT

The traditional specification used in the pass-through literature is based on the regression of the inflation on the nominal effective exchange rate. Following Kabundi & Mlachila (2019), the first stage involves estimating a time series regression of inflation on nominal effective exchange rate (monthly data) to obtain time-varying ERPT based on 60 months rolling window for the large period 1990m1-2020m1. The time-varying parameter (β_t) ERPT is as follows:

$$\Delta cpi_t = \alpha_t + \beta_t \Delta neer_t + \varepsilon_t , \qquad (6)$$

Where Δcpi is a growth rate of monthly consumer price index over the previous year's period. $\Delta neer$ is defined as a change of nominal effective exchange rate, ε_t is the error term and i.i.d (0, σ2). According to Eq. (6), ERPT is positive in the sense that the depreciation in the currency value (↑ e) increases the inflation and the appreciation of the importing country's currency (↓ e) decreases the price of imported goods. The primary concern in the first stage of this study is the ERPT elasticity which corresponds to the coefficient β_t which is expected to be bounded between 0 and 1.

International Journal of Management, Accounting and Economics
Vol. 8, No. 11, November, 2021
ISSN 2383-2126 (Online)

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Second Stage: Towards a threshold specification

Once credibility index is computed, as in Taylor (2000), I propose a statistic PTR model with individual fixed effects developed by Hansen (1999) which enables us to split our sample of IT countries into different credibility regimes. The aim of this analysis is to link the CBC on the extent of the ERPT. The level of the CBC throughout our sample would give further evidence of the importance of macroeconomic factors in a more comprehensive extent such as credibility environment as an important determinant of the ERPT. To reach this, I attempt to divide the panel of countries into different groups based on the CBC level and then estimate the weight of the ERPT relative to the imported goods for those different groups. The idea is to compare the extent of pass-through for different central banks' credibility regimes and to depict outcomes about the reasons for cross-country differences in the ERPT.

Following Hansen (1999), I can rewrite the model for two regimes (a single threshold) as follows:

$$pt_{i,t} = \begin{pmatrix} \theta_0 + \theta_1 itg_{i,t} + \theta_2 og_{i,t} + u_{i,t} & if\ CR_{i,t} \le \gamma \\ \theta_3 + \theta_4 itg_{i,t} + \theta_5 og_{i,t} + u_{i,t} & if\ CR_{i,t} > \gamma \end{pmatrix}, \qquad (7)$$

an alternative intuitive way of the structural equation of interest (7) is:

$$pt_{i,t} = \theta_i + \varphi_1' w_{i,t} I_{(CR \le \gamma)} + \varphi_2' w_{i,t} I_{(CR > \gamma)} + u_{i,t}, \qquad (8)$$

where, the dependent variable pt is the ERPT, $itg_{i,t}$ denotes Import to GDP ratio and $og_{i,t}$ is the Output Gap which is used to increase the explanatory power of the model. $\varphi' = (\theta_i)'$, $w_{i,t} = (itg_{i,t}, og_{i,t})'$ and $I_{(.)}$ is the indicator function and γ denotes a threshold parameter. The dependent variable pt and the threshold variable (credibility index) CR are scalar, and the regressor $w_{i,t}$ denotes 2 vectors of $og_{i,t}$ and $itg_{i,t}$. θ_i is the individual fixed effect for each forecaster (the level of country), $u_{i,t}$ is the remaining error term assumed to bei.i.d (0, σ2) and finally the subscript i indexes the individual and the subscript t indexes time[1].

Three remarks are associated to this model: first, divided observations into two regimes depend on whether the threshold variable CR is smaller or larger than the threshold parameter γ. Second, threshold variable CR and regressors $w_{i,t}$ should be time-variant in order to identify the slopes. Third, as mentioned in Hansen (1999), the

[1] - We have run a Hausman test which compares the random versus fixed effects under the null hypothesis that the individual effects are not correlated with the other regressors in the model. According to the result, the null hypothesis of random effects is strongly rejected in favor of the fixed effects. In the case of the stationarity of our variables, we have checked the augmented Dickey-Fuller Fisher unit root test which has rejected the null hypothesis of a unit root in all variable. To save space, the results from Hausman test and panel unit root tests are not reported in the paper, but are available upon request.

individual effects θ_i are not different in the two regimes. So, not only it would be possible to consider a constant or N individual constant specific to each regime, but it would also increase the number of parameters of the model. For this reason, the regimes are separated by their differing regressors slope, $\varphi_1^{'}$ and $\varphi_2^{'}$.

Generally, this model can be considered with more than two regimes[1]. However, we limit our attention to the model with three regimes and two threshold parameters given by:

$$pt_{i,t} = \theta_i + \varphi_1^{'} w_{i,t} I_{(CR \le \gamma_1)} + \varphi_2^{'} w_{i,t} I_{(\gamma_1 < CR \le \gamma_2)} + \varphi_3^{'} w_{i,t} I_{(CR > \gamma_2)} + u_{i,t}, \qquad (9)$$

γ_j is sorted by $\gamma_1 < \gamma_2$.

Since Hansen (1999) recommends, γ and the slope coefficients, $\varphi_1^{'}$ and $\varphi_2^{'}$ of equation (8) can be estimated by OLS approach for any given γ:

$$S_1(\gamma) = \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{u}_{i,t}^2 (\gamma) \ , \qquad (10)$$

$S_1(\gamma)$ computes the sum of squared errors conditional on a value of γ. The threshold parameter γ is estimated by minimizing the sum of squared ($S_1(\gamma)$):

$$\hat{\gamma} = ArgMin S_1(\gamma) \qquad \gamma \in \Lambda \ , \qquad (11)$$

as discussed in Hansen (1999) and Candelon et al (2013), it is undesirable for a threshold to be chosen which sorts too few observations into one or another regime. For this reason, they consider an optimization domain, confirming minimum percentage of the observations stand in each regime.

The null hypothesis is $H_0 : \varphi_1 = \varphi_2$ if the threshold effect of equation (8) is tested to be statically significant. In this case, there is no threshold effect and the model is equivalent to a linear model. To test of this hypothesis I use a standard test, representing S_0 as the sum of squares of the linear model and the approximate likelihood ratio test of H_0 is based on the following:

$$F_1 = {S_0 - S_1(\hat{\gamma})} \Big/ {\hat{\sigma}^2} \ , \qquad (12)$$

where $\hat{\sigma}^2$ is a constant estimate of σ^2.

[1] - The estimation process proposed by Hansen allows one to take into account a model with *K* regimes and K-1 thresholds (see, Hansen (1999) and Candelon et al. (2013)).

International Journal of Management, Accounting and Economics
Vol. 8, No. 11, November, 2021
ISSN 2383-2126 (Online)

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The main challenge under the null is that the threshold parameter γ is not identified. Therefore, the asymptotic distribution of F_1 is not standard and does not correspond to a chi-squared distribution. As Hansen (1996) suggested, using a bootstrap procedure is a reliable way to obtain the asymptotic distribution and construction of the P-values. In the case of panel models, we also use bootstrap simulations to compute the critical values of the statistics' distribution of the tests on the number of thresholds. If the P-value associated with F1 let us to reject the null hypothesis (no threshold effect), we will discriminate between one and two thresholds. In such circumstances, a likelihood ratio test of one threshold versus two thresholds is based on the statistic:

$$F_2 = {S_1(\hat{\gamma}_1) - S_2(\hat{\gamma}_1, \hat{\gamma}_2)} \Big/ {\hat{\sigma}^2}, \qquad (13)$$

where, $\hat{\gamma}_1$ and $\hat{\gamma}_2$ are the estimated thresholds of the model with three regimes and $S_2(\hat{\gamma}_1, \hat{\gamma}_2)$ denotes the sum of squared errors. If F_2 is larger than the critical value of the non-simulated distribution, the one-threshold hypothesis will reject in favor of the two-threshold hypothesis.

Empirical Results

First Stage: ERPT

As mentioned above, following Kabundi & Mlachila (2019), the first step is to estimate ERPT coefficients (Eq. 6). As shown in Fig. 1, Romania and Ghana as emerging countries have the most ERPT movements among IT group. Although exchange rate has raised for most countries during the financial crisis (2007-2009), but there is a descending trend in the ERPT for almost all countries except for Armenia and Romania (fig.1).

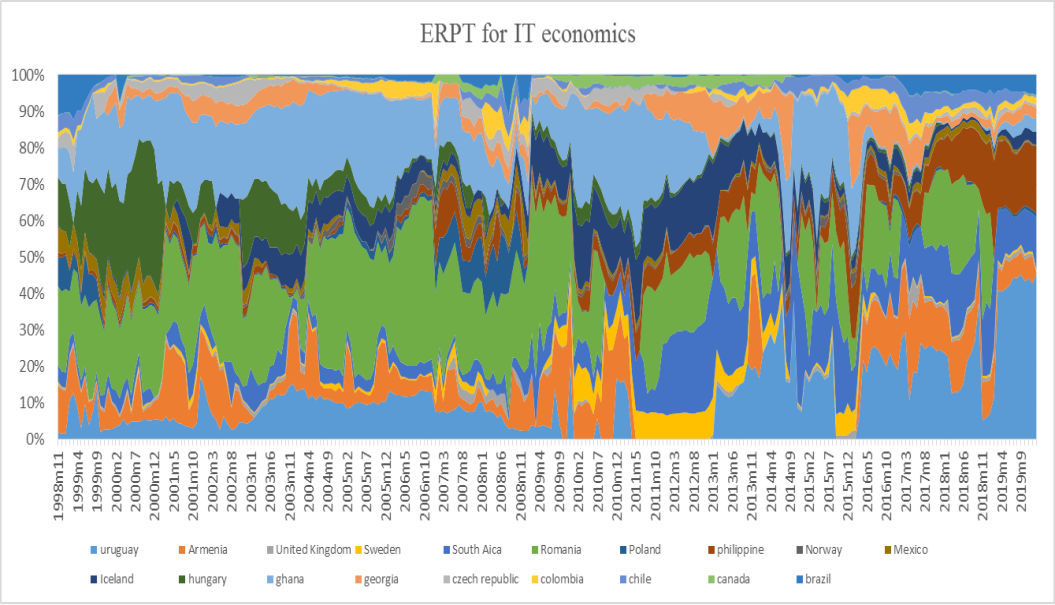

Fig 1. Exchange rate pass-through evolution in IT economies *CBC indicator*

International Journal of Management, Accounting and Economics
Vol. 8, No. 11, November, 2021
ISSN 2383-2126 (Online)

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As previously mentioned, I compute the CR_{NTLLR} (Eq. 5) as a nonlinear index. To do so, in line with Levieuge, Lucotte, & Ringuedé (2018) I use the midpoint of the target range as an inflation target. In their sample of 5 advanced countries, Neuenkirch & Tillmann (2014), use 60 months memory of inflation rate which is able to disentangle actual credibility losses from temporary ”credibility losses” resulting from the exchange rate movement's behavior. Thus, in the case of the average of past inflation rates, I rely on Neuenkirch & Tillmann (2014) way and select 60 months inflation lag length.

In line with Levieuge, Lucotte, & Ringuedé (2018) CBC index is between 0 and 1, with 1 for full credibility if the average of the past inflation completely meet the target. At the extreme opposite, CBC= 0 indicates that the corresponding central bank is not credible. The figure 2 gives the profile of this indicator for inflation target = 3%, with the horizontal axis representing $\bar{\pi}$. As expected, the figure is non-linear. Fig. 2 nicely shows how CBC with negative deviations of the past inflation from the target are less likely compromised than positive ones. Although any deviation from target is loss for CBC, but the positive deviation signals a higher loss in credibility than an equivalent negative one. One of the most important features of this indicator is that the marginal loss in credibility is decreasing with ($\bar{\pi}_{t-\alpha} - \hat{\pi}$). An inverted-U credibility curve, with a higher slope in the neighborhood of the target than at its extremities can justify this notion. Assume that $\hat{\pi}$ = 3%. The past inflation rate that grows from 10 to 12% should not hurtle with an exhibitive loss in credibility, (because of the initial $\bar{\pi}$ = 10%). Quite the contradict, a growing the past inflation rate, from 3 to 6%, must express a higher marginal loss (100%) in CBC (see Fig. 2).

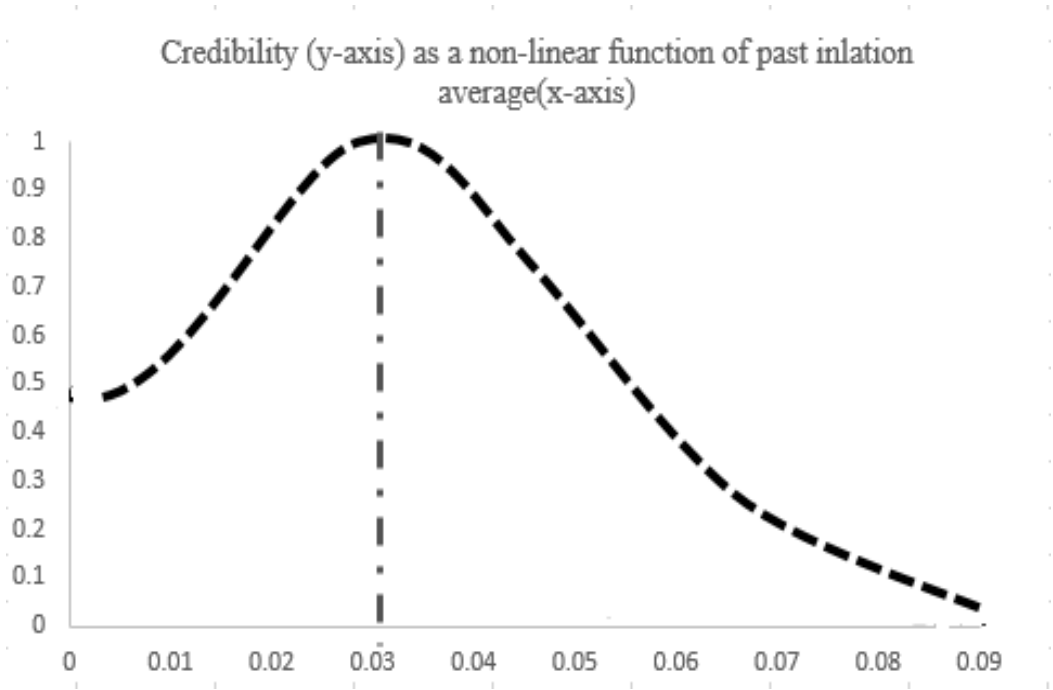

Fig.2 Non-Linear effect of CBC index on the deviation of the past inflation from target (3 percent).

Second Stage: CBC, ERPT and Threshold Effect

Once computing the ERPT and CBC index, in order to determine the number of regimes or testing the threshold, I follow the bootstrapping method and the sequential procedure proposed by Hansen (1999) to obtain the approximations of the F statistics and their bootstrap P-values for IT countries. The F statistics contain F1 and F2 to consider the null hypotheses of one regime (none threshold) and two regime (one threshold) respectively.

Once one or more significant thresholds are found (based on Eq. 8), I can split the country sample into different regimes based on their degree of CBC and then estimate the effect of imported goods and output gap on ERPT for each regime in order to make a comparison between different groups[1].

Table 2 reports tests statistics of F1, F2 for single threshold, double threshold, and their bootstrap P-values. I find a highly significant F1 test for a single threshold with a bootstrap P-value =0.00. However, the test statistic for a second threshold is far from being statistically significant with a p-value of 1.00. Therefore, the sequential test procedure implies two regimes and one threshold in the model for the sample of 19 IT economies.

Table 2. Hansen (1999) test for multiple thresholds.

Threshold value (CBC)	F	P-value	95% confidence interval
Single threshold effect test (H0: no threshold)			
0.35	256.56	0.00	[0.2748 , 0.3610]
Double threshold effect test (H0: at most one threshold)			
0.35	23.05	1.00	
0.79			

Note: Table reports threshold estimates $\hat{\gamma}$. P-values are calculated by 1000 simulations. The Fisher type statistic (F1) denotes the test (the null hypothesis) of no threshold against one threshold and F2 corresponds to the test one threshold against two thresholds.

Table 2 also represents the estimated parameter of one threshold CBC of 35 percent. Finally, all observations will be objectively split into two regimes depending on whether the CBC is lower or higher than the threshold value $\hat{\gamma}_1$. Accordingly, I define two groups of countries: a low credibility regime including central banks with mean annual credibility degrees of less than 35 percent, and a high credibility regime comprising central banks with annual mean credibility exceeding 35 percent. According to this classification, I consider central banks of Armenia, Georgia, Ghana, Romania and Uruguay with low credibility and Brazil, Canada, Chile, Colombia, Czech Republic, Hungary, Iceland, Mexico, Philippines, Poland, South Africa, Norway, Sweden, and United Kingdom with high CBC.

[1] - As Hansen (1999) uses the threshold values to divide his sample of US firms into low debt and high debt firms.

In order to make a comparison between different levels of CBC and draw conclusions about the link between the extent of ERPT and the credible monetary environment, I estimate imported goods elasticity to ERPT and the impact of output gap for each class of CBC. Table 3 presents estimations for each group of countries based on CBC. In view of the result, a higher credible central bank experiences the degree of ERPT equal to 12 percent, while 1 percent increase of imported goods ratio to GDP causes a raise in pass-through of exchange rate by 54 percent for countries with lower CBC. Obviously, in line with Taylor (2000), this finding supports the conventional wisdom on the positive link between lower inflation environment with more credible central bank and the level of ERPT. That is, countries with lower level of credibility or, in other hand, central banks that have an improper performance in control of inflation and the expected inflation, should have the higher level of pass-through. Our results provide evidence on the regime-dependence of ERPT with regard to the credibility of the monetary authority. Particularly, this finding could be an important source of heterogeneity and non-linearity in ERPT across countries.

Table 3. Estimation of model with fixed effect

Dependent variable: $pt_{i,t}$	Low CBC(CR<0.35)	High CBC(CR>0.35)
Constant	0.009** (0.03)	0.01*** (0.01)
$itg_{i,t}$	0.54*** (0.13)	0.12*** (0.03)
$og_{i,t}$	1.69 (2.51)	0.83 (0.57)

Note: ** and *** denote significance at the 5% and 1% levels, respectively. Standard errors are in parentheses.

Main differences of this study with De Mendonça & Tiberto (2017) and Kabundi & Mlachila, (2019) are in two important cases: first, using a nonlinear credibility index with regard to the past performance of central bank. Second, providing a PTR model giving more accurate and logical threshold based on the level of CBC to split countries. My results are in line with empirical results of Ben Cheikh & Louhichi (2016) and Shintani, Terada-Hagiwara & Tomoyoshi (2013) where use a PTR model and a smooth transition regression framework, respectively, to show that there is a strong evidence for the dependence of ERPT on the inflation regime. Nonetheless, this study has a fundamental difference with mentioned studies as I take the significant role of the credibility into account as a basis of adjustment. As pointed out in Taylor (2000) and in line with my results, a more credible central bank, in a comprehensive extent, can keep inflation under control and mitigate the level of ERPT.

Robustness check

To check the reliability of the estimated model across identified regimes, I take a dynamic panel data model into account by including the lagged ERPT as an explanatory variable. Based on the estimated threshold value obtained from Eq. (7), ERPT elasticity is estimated for the identified regimes using a generalized method of moments (GMM) estimator. This method allows me to reverse causality problem and circumvent the

potential endogenous bias (Arellano & Bond, S, 1991). Thus, I mutate the model to have the form of a dynamic panel data model as follows:

$$pt_{i,t} = \begin{pmatrix} \theta_0 + \theta_1 pt_{i,t-1} + \theta_2 itg_{i,t} + \theta_3 og_{i,t} + u_{i,t} & if\ CR_{i,t} \le \gamma \\ \theta_4 + \theta_5 pt_{i,t-1} + \theta_6 itg_{i,t} + \theta_7 og_{i,t} + u_{i,t} & if\ CR_{i,t} > \gamma \end{pmatrix}, \qquad (14)$$

As shown in the table 4, the regime-dependence of ERPT to CBC level is still robust. Within the low-credibility regime, a 1% increase in the imported goods ratio leads to a rise in ERPT by 41%, while the rate of the ERPT elasticity is found to be less likely compared to the estimates obtained from the equation (7) in the high credibility regime by roughly 11%. In countries with more credible central bank, when CBC is exceeding the threshold of 35%, the degree of the past pass-through strongly seems to have a lower impact on the current ERPT level than the countries with lower credibility[1]. In all, the presence of a threshold effect in the extent of the ERPT remains statistically significant across the robustness check.

Table 4. Estimation results using dynamic GMM panel-data estimation with CBC index as a threshold variable

Dependent variable: $pt_{i,t}$	Low CBC(CR<0.35)	High CBC(CR>0.35)
Constant	0.03** (0.05)	0.12*** (0.02)
$pt_{i,t-1}$	0.57** (0.07)	0.35*** (0.04)
$itg_{i,t}$	0.41*** (0.2)	0.11*** (0.08)
$og_{i,t}$	3.75 (2.51)	0.08 (0.88)
Sargan test	5.64 (0.49)	8.54 (0.36)

Note: This table reports the estimation results of Eq. (14) using GMM estimator. ** and*** denote significance at the 5% and 1% levels and the standard errors are in parentheses. The null hypothesis of the Sargan test shows that the model and over identifying conditions are correct specified with p-values reported in parentheses.

Concluding Remarks

In this paper, in line with Taylor (2000), I use a new approach to shed light on the role of CBC in explaining the extent of the ERPT. In order to consider the significant role of the CBC in the level of pass-through, in the best of my knowledge, all done studies in this notion not only use a linear CBC index but they also take the credibility index into account as an explanatory variable for the traditional classification of the countries such as advanced, emerging or developing. However, this study proposes a non-linear CBC index which is based on the past performance of the central bank to emphasis negative deviations of the past inflation from the target are less likely to indicate a loss in the

[1] - As shown in tables (3and 4), in the case of the output gap, there is a positive effect on the ERPT in both estimations but statistically insignificant.

credibility than the positive ones. Furthermore, a PTR framework is used to select the appropriate threshold value to split our sample of 19 IT economies into different regimes based on the CBC.

To do so, I used a time-varying rolling window regression to obtain the ERPT based on the country data. Once the CBC index is gained, I model a PTR set including 19 countries over the large period (1991–2019) to provide the evidence of the regime-dependence of ERPT with regard to the credibility of central bank. My empirical results show that emerging countries such as Romania and Ghana have the most ERPT movements among IT group. In the second stage, the finding indicates that there is one threshold point and a significant regime-dependence of the pass-through on CBC. When CBC level is below 35% within a high-inflation environment the degree of the pass-through relative to the weight of imported goods is found to be higher. However, with the shift towards high-credibility regime, when CBC level is exceeding the threshold of 35%, the extent of pass-through is significantly declining.

In terms of policy implications, it implies that a proper performance of central bank (the ability of the central bank to meet the commitment) and the rise of credibility over time significantly would ensure the better control of the degree of pass-through which can lead to the higher macroeconomic stability. However, interesting questions in this background are that what determinants the performance and subsequently credibility of the central bank? How does the institutional structure of a country's central bank affect its performance and credibility? Combining our suggested credibility index with the literature on the political economy of the CBC would be strongly relevant for such research.

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International Journal of Management, Accounting and Economics
Vol. 8, No. 11, November, 2021
ISSN 2383-2126 (Online)

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Appendix

Table 5. Exchange rate regime and inflation targeting.

Countries	Exchange rate regime	Effective IT adopt date	Inflation target (%) at the start of adoption
Albania	floating	2009m1	2_4
Argentina	floating	2016m9	12_17
Armenia	floating	2006m1	2.5_5.5
Australia	Free floating	1993m4	2_3
Azerbaijan	floating	2019m12	2_6
Bangladesh	floating	2015	6.5
Belarus	floating	2015	5
Botswana	Crawling peg	2006m2	3_6
Brazil	floating	1999m6	6_10
Canada	Free floating	1991m2	2_4
Chile	Free floating	1999m9	2.4_4.5
China	Managed floating	2015	3
Colombia	Floating	1999m9	14_16
Dem.REP.Congo	Conventional peg	2019	7
Costa Rica	Managed floating	2018m2	2_4
Czech Republic	Floating	1998m1	5.5_6.5
Dominican REP	Managed floating	2012m1	3_5
Eswatini	Conventional peg	2019	3_7
Gambia	Other managed arrangement	2019	5
Georgia	Floating	2009m1	3
Ghana	Floating	2007m5	6.5_10.5
Guatemala	Stabilized arrangement	2005m1	4_6
Hungary	Floating	2001m6	6_8
Honduras	Crawling peg	20017m8	3_5
Iceland	Floating	2001m3	1_4
India	Floating	2016m8	2_6
Indonesia	Stabilized arrangement	2005m7	5_7
Jamaica	Floating	2017	4_6
Japan	Free floating	2013m1	2
Kazakhstan	Floating	2015m8	4
Kenya	Stabilized arrangement	2017	7.5_2.5
Kyrgyzstan	Other managed arrangement	2018	5_7
Malawi	Stabilized arrangement	2019	5
Mexico	Free floating	2001m1	0_6.5
Moldova	Floating	2013	3.5_6.5
Mongolia	Floating	2007m6	4_6
Mozambique	Floating	2017	5.6
Nepal	Conventional peg	2018	6
New Zealand	Floating	1990m1	3_5

Countries	Exchange rate regime	Effective IT adopt date	Inflation target (%) at the start of adoption
Nigeria	Stabilized arrangement	2016	6_9
Norway	Free floating	2001m3	2.5
Pakistan	Stabilized arrangement	2019	6
Paraguay	Floating	2011m5	2_6
Peru	Floating	2002m1	1.5_3.5
Philippines	Floating	2002m1	5_6
Poland	Free floating	1998m10	7.5_9.5
Romania	Floating	2005m8	6.8_8.5
Russia	Free floating	2014m1	4
Samoa	Conventional peg	2019	3
Serbia	Crawl-like arrangement	2006m9	4_8
South Africa	Floating	2000m2	3_6
South Korea	Floating	2001m1	2_4
Srilanka	Crawl-like arrangement	2017	4_6
Sweden	Free floating	1993m1	2
Switzerland	Floating	2000	2
Tajikistan	Stabilized arrangement	2018	5_9
Tanzania	Stabilized arrangement	2017	5
Thailand	Floating	2000m5	0-3.5
Tonga	Conventional peg	2019	5
Turkey	Floating	2006m1	3_7
Uganda	Floating	2011	5
United Kingdom	Free floating	1992m12	2
Uruguay	Floating	2007m1	3_7
USA	Free floating	2012m1	2
Uzbekistan	Stabilized arrangement	2020m1	5
Ukraine	Floating	2015m8	4_6
Vietnam	Stabilized arrangement	2005	6.5
Zambia	Floating	2012m4	6_8

Sources: Central bank news, IMF, Scott Roger (2009).

HOW TO CITE THIS ARTICLE

Kamal, E. (2021). Exchange Rate Pass-Through and Central Bank Credibility: Evidence on Inflation Targeting Countries. *International Journal of Management, Accounting and Economics*, 8(11), 795-815.

DOI: 10.5281/zenodo.5987713

URL: https://www.ijmae.com/article_144384.html