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JEL: C23, E31, F31, F40
Keywords: Exchange Rate Pass-Through, Import Prices, Panel Threshold

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Revisiting the Role of Inflation Environment in the Exchange Rate Pass-Through: A Panel Threshold Approach

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Abstract

This paper sheds new light on the role of inflation regime in explaining the extent of exchange rate pass-through (ERPT) into import prices. In order to classify his sample of 24 developing countries by regimes of inflation, Barhoumi [(2006), "Differences in long run exchange rate pass-through into import prices in developing countries: An empirical investigation", Economic Modeling, 23 (6), 926-951.] chose an arbitrary threshold of 10% to split sample between high and low inflation regimes. For more accuracy, our study proposes to use a panel threshold framework where a grid search is used to select the appropriate threshold value. In a larger panel-data set including 63 countries over the period 1992-2012, we find that there are two thresholds points that are well identified by the data, allowing us to split our sample into three inflation regimes. When estimating the ERPT for each group of countries, we point out a strong regime-dependence of pass-through to inflation environment, that is, the class of countries with higher inflation rates experiences the higher degree of ERPT.

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1 Introduction

The study of the degree of Exchange Rate Pass-Through (ERPT) into import prices is an issue of key importance for the conduct of monetary policy. In the recent years, several studies have put forth the substantial role of inflation regime in explaining the lowering rates of pass-through across the industrial countries (see e.g. GAGNON and IHRIG, 2004; BAILLIU and FUJII, 2004; CHOUDHRI and HAKURA, 2006). This intriguing outcome was popularized by TAYLOR (2000) which explains that the shift towards more credible monetary policy and thus, a low-inflation regime, would reduce the transmission of the exchange rate changes to domestic prices. This assumption is very appealing and has received strong empirical support in the recent literature.

In a large database that includes 1979-2000 data for 71 countries, CHOUDHRI and HAKURA (2006) provide strong evidence of a positive and significant association between the pass-through and the average inflation rate across countries. According to the authors, the inflation environment dominates other macroeconomic variables in explaining cross-regime differences in the pass-through. This outcome was achieved by classifying their different countries by regimes of inflation. In other words, they classified their countries into three groups: weak inflation (less than 10%), moderate inflation (between 10 and 30%) and high inflation (more than 30%), with classification is based on the average of the rate of inflation (mean annual inflation). In a similar vein, BARHOUMI (2006) divided a sample of 24 developing countries between high and low inflation regimes, depending on whether inflation rate is smaller or larger than 10%. Thus, the author divided countries in two regimes: country characterized by mean annual inflation less than 10% will be considered as low inflation countries, while countries characterized by mean annual inflation higher than 10% will be considered to be high inflation countries.

Nevertheless, country classification used these studies is somewhat arbitrary, in the sense that the authors used an ad hoc method to select their sample splits. In our paper, we propose to use panel threshold techniques, introduced by HANSEN (1999), to deal with the sample split problem. This methodology enables us to divide our sample into classes based on the value of inflation levels. For more accuracy, a grid search is used to select the appropriate threshold value within a panel threshold framework. Therefore, in a larger panel-data set including 63 countries over the period 1992-2012, we propose to test for the number of inflation thresholds and to estimate both the threshold levels. For the purpose of our analysis, we use the estimated threshold to divide our sample of countries into different groups with respect to their macroeconomic environment, namely the inflation regime. Then, we estimate the ERPT elasticity for each class of countries in order to make a comparison between different groups. To the best of our knowledge, the present paper is the only study that applying panel threshold method in this context. It is important to note that our paper is a contribution to the study of BARHOUMI (2006) by focusing on the sensitivity of import prices to exchange rate movements.[1]

The remainder of the paper is organized as follows. In section 2, we describe the analytical framework that underlies our empirical specification. In section 3, the data set and their properties are discussed. In Section 4, we briefly discuss the econometrics of the panel threshold model. Section 5 presents the main empirical results and Section 6 concludes.

2 The ERPT model

To illustrate the point, consider an imperfectly competitive foreign firm exporting its product to a given domestic country (destination market) while facing competition from the producers in the same market. As a price setter, the firm solves the following profit maximization problem:

$$\max_{p} \Pi = e^{-1} p^m q(p^m, p^d, y) - c(q(.), w^*) \tag{1}$$

where e is the exchange rate measured by units of the importer's currency per unit of the exporter's currency, p^m is the import price of the product in the importing country, and $q(.)$ is the demand for the product that depends not only on own price but also on the price of the domestic competing product p^d and the income level y. The production cost c(.) is determined by the level of the demand for the product and the input price w^* measured in the exporter's currency units.

The first-order condition for a profit maximizing firm leads to the following equation:

$$p^m = eC_q\mu \tag{2}$$

where C_q is the marginal cost and $\mu =$ is the markup of price over marginal cost. The markup is further defined as $\mu = \eta/(\eta - 1)$, where η is the price elasticity of demand for the product that depends on variables specific to importing country, mainly, demand conditions y and the price of the competing product p^d. According to equation (2), we see that pass-through elasticity depends crucially on the behavior of the marginal cost and markup. In general, ERPT is positive in the sense that a depreciation in the importing country's currency ($\uparrow e$) increases the

[1] We note that CHOUDHRI and HAKURA (2006) studied the pass-through of exchange rate to consumer prices.

import price of good; while an appreciation of the currency value ($\downarrow e$) raises the price of imported good.

As stated by the import price equation (2), in estimating ERPT it is necessary to isolate the exchange rate effect from other effects, i.e. the exporter's cost shifter, importer's demand conditions, and the price of the domestic competitor. Thus, we can capture the arguments of the import price equation (2) through a log-linear regression specification similar to that tested throughout the ERPT literature:

$$p_{it}^{m} = \alpha_i + \phi e_{it} + \gamma y_{it} + \delta w_{it}^{*} + \varepsilon_{it}, \tag{3}$$

As discussed by CAMPA and GOLDBERG (2005), biased estimates of the pass-through coefficient could arise if foreign costs or proxies for markup are correlated with exchange rates but omitted from the regression. Variants of equation (3) are widely used as empirical specifications in the pass-through literature.[2] While the general approach of is very similar in the pass-through studies, there are a few differences between then regarding the specification and the list of control variables. Our primary concern in this study is the pass-through elasticity which corresponds to the coefficient on the exchange rate ϕ which is expected to be bounded between 0 and 1. A one-for-one pass through to changes in import prices, known as a complete ERPT, is given by $\phi = 1$. In this case, exporters let the domestic currency import prices affected by exchange rate move. While, when exporters adjust their markup, a partial or incomplete ERPT occurs and $\phi < 1$.

3 Data

To give further insight on the role of inflation environment, we use a large database that comprises 1992-2012 annual data for 63 countries. Our sample is quite heterogeneous in terms of levels of inflation which enables us to provide clear picture on the link between pass-through and inflation (see Table 1). For each country, data was collected following a cascade order and choosing when possible only one institutional source, namely IMF's *International Financial Statistics* and OECD's *Main Economic Indicators* and *Economic Outlook*, in that order.

Concerning our dependent variable in equation (3), i.e. the domestic import prices p_{it}^{m}, we use the price of non-commodity imports of goods and services. This represents import prices of core goods by excluding primary raw commodities because of their marked volatility. For all countries for the exchange rate we employed the nominal effective trade weighted series, with an increase means depreciation of the national currency, and a decrease means appreciation.

[2] See GOLDBERG and KNETTER (1997) for a survey of this literature.

Table 1: Selected characteristics of inflation (1992-2012)

Country	Mean annual inflation (%)	Maximum	Minimum	Standard deviation
Algeria	10,22	31,67	0,34	10,13
Argentina	115,02	2313,96	-1,17	470,06
Australia	2,62	7,27	0,25	1,52
Austria	2,24	4,03	0,51	0,95
Belgium	2,23	4,49	-0,05	0,95
Bolivia	7,47	21,45	0,93	5,13
Botswana	9,49	16,17	6,56	2,50
Brazil	370,38	2947,73	3,20	798,33
Bulgaria	85,36	1058,37	2,16	219,70
Burkina Faso	3,53	25,18	-1,99	5,66
Canada	2,15	5,62	0,19	1,16
Chile	6,96	26,04	1,05	6,42
China	4,67	24,24	-1,41	6,09
Colombia	12,74	30,37	2,28	9,12
Costa Rica	12,72	28,71	4,50	5,80
Côte d'Ivoire	4,25	26,08	-0,81	5,44
Czech Republic	4,42	10,63	0,11	3,29
Denmark	2,16	3,40	1,16	0,52
Ecuador	25,29	96,09	2,28	23,68
Finland	2,02	6,10	0,00	1,44
France	1,82	3,38	0,09	0,75
Gabon	2,70	36,12	-11,69	8,42
Germany	1,90	5,08	0,31	1,10
Greece	6,62	20,40	1,21	5,57
Hungary	12,94	34,23	3,55	9,39
Iceland	5,19	15,51	1,55	3,59
India	7,88	13,87	3,68	3,18
Indonesia	10,64	58,39	3,72	10,78
Iran	19,48	49,66	7,63	8,87
Ireland	2,52	5,56	-4,48	2,06
Italy	3,10	6,50	0,75	1,51
Japan	0,37	3,30	-1,35	1,18
Jordan	4,50	16,19	-0,68	3,96
Korea, Republic of	4,25	9,30	0,81	2,09
Luxembourg	2,35	3,70	0,37	0,88
Mexico	11,65	35,00	3,41	9,76
Morocco	2,90	7,99	0,62	2,17
Netherlands	2,25	4,16	1,17	0,73
New Zealand	2,40	6,10	0,28	1,31
Nigeria	20,24	72,84	5,38	18,44
Norway	2,16	4,11	0,47	0,94
Pakistan	9,23	20,29	2,91	4,07
Paraguay	11,44	37,26	2,59	7,62
Philippines	6,44	18,49	2,29	3,53
Poland	38,08	555,38	0,79	111,77
Portugal	4,05	13,37	-0,84	3,10
Romania	61,06	255,17	3,33	78,67

Note: Data are from International Financial Statistics of IMF. Inflation rates are in percentage.

Table 1: *Continued*

Country	Mean annual inflation (%)	Maximum	Minimum	Standard deviation
Senegal	3,11	32,29	-1,75	6,61
Singapore	2,03	6,52	-0,39	1,72
Slovak Republic	6,10	13,41	0,96	3,45
Slovenia	7,74	32,86	0,86	7,39
South Africa	7,61	15,33	1,39	3,46
Spain	3,45	6,72	-0,29	1,51
Sweden	2,29	10,47	-0,49	2,64
Switzerland	1,44	5,88	-0,67	1,66
Thailand	3,66	7,99	-0,85	2,12
Tunisia	4,11	8,19	1,98	1,50
Turkey	44,90	106,26	6,25	32,65
United Kingdom	2,70	7,53	0,79	1,69
United States	2,72	5,40	-0,36	1,08
Uruguay	25,97	112,53	4,36	30,51
Venezuela	33,22	99,88	12,53	19,19
Zambia	43,17	183,31	6,43	48,81

Note: Data are from International Financial Statistics of IMF. Inflation rates are in percentage.

Next, the marginal costs of foreign producers are difficult to measure since they are not directly observable, and thus need to be proxied. A conventional practice is to use a weighted average of trade partners' costs as in CAMPA and GOLDBERG (2005) and BAILLIU and FUJII (2004). Following this, the foreign costs of each EA country's major trade partners is derived implicitly from the nominal and real effective exchange rate series as follows: $w^* \equiv q_t - e_t + ulc_t$, where ulc_t is the domestic unit labour cost (ULC) and q_t is the ULC-based real effective exchange rate. Given that the nominal and real effective exchange rate series are trade weighted, this proxy provides a measure of trading partner costs, with each partner weighted by its importance in the importing country's trade. However, we note that domestic unit labour cost (ulc_t) variable is not available for all the countries in our sample, thus in some cases we use the wholesale price index or the Consumer Price Index (see BARHOUMI, 2006). As regards foreign firm's markup, we use the real gross domestic product y_t to proxy for changes in domestic demand conditions.[3] Finally, due to the large size of our sample, we test for the presence of cointegration relationship in our panel data. Adding the cross-section dimension to the time series dimension would increase the power of unit-root tests, leading to possible long-run equilibrium in ERPT equation. However, when we employ WESTERLUND (2007) panel cointegration tests we are cannot reject the null of no cointegration. In view of this evidence, we assume variables in (3 are

[3] To check the robustness of the benchmark model, in addition to the output gap, we have included a measure of producer price index as a proxy for the competitors prices in the importing country (see OLIVEI, 2002; BUSSIÈRE, 2012, among others).

not cointegrated and estimate this relation in the following first-difference form:

$$\Delta p_{it}^{m} = \alpha_i + \phi \Delta e_{it} + \gamma \Delta y_{it} + \delta \Delta w_{it}^{*} + \varepsilon_{it}, \tag{4}$$

4 Empirical Methodology

In order to analyze the role of inflation environment in the spirit of TAYLOR (2000), we propose a threshold panel approach which enables us to split our sample of 63 countries in different inflation regimes. The aim of our analysis is to link inflation environment to the extent of pass-through. Inflation regime throughout our sample would give further evidence on the importance of macroeconomic factors such as inflation environment as an important determinant of ERPT. To achieve this, we try to split our panel of countries into different groups with respect to the level of inflation rates, and then to estimate the ERPT for those different groups. The idea is to compare pass-through elasticity for different country regimes and to draw conclusion about the reasons of cross-country differences in ERPT into import prices.

Previous studies have followed a somewhat arbitrary country classification, by using an ad hoc method to select their sample splits. For instance, BARHOUMI (2006) divided a sample of 24 developing countries between high and low inflation regimes, depending on whether inflation rate is smaller or larger than 10%. Similarly, CHOUDHRI and HAKURA (2006) classify their 71 countries into three groups, namely low, moderate and high inflation groups which are defined as consisting of countries with average inflation rates less than 10%, between 10% and 30% and more than 30%, respectively.

To deal with the sample split problem, we propose here to use panel threshold techniques, introduced by HANSEN (1999), where a grid search is used to select the appropriate threshold. This methodology enables us to divide our sample into different classes based on the value of inflation rate.

HANSEN (1999) introduces a panel threshold model for a single and multiple threshold levels, so that the observations can be split into two or more regimes depending on whether the threshold variable is above or below some threshold values. Following HANSEN (1999), we can rewrite our pass-through equation for a single threshold model (two regimes) as follow:

$$p_{it}^{m} = \begin{cases} \alpha_i + \beta_1^{'} x_{it} + \varepsilon_{it}, & \pi_{it} \leq \theta, \\ \alpha_i + \beta_2^{'} x_{it} + \varepsilon_{it}, & \pi_{it} > \theta. \end{cases} \tag{5}$$

The dependent variable of our ERPT panel threshold model is the import prices, p_{it}^{m}, and the explanatory variables - Exchange rate, domestic demand and foreign costs - are included the vector $x_{it} = (e_{it}, y_{it}, w^*_{it})'$. α_i denotes the level of country i fixed-effect and ε_{it} is a zero mean, finite variance, i.i.d. disturbance. The two regimes are distinguished by different regression slopes, β_1 and β_2, depending on whether the value of the threshold variable, i.e. inflation rate π_{it}, is smaller or larger than the threshold θ.[4] If the threshold variable π_{it} is below or above a certain value of θ, then the vector of exogenous variable x_{it} has a different impact on the dependent variable, p^m_{it}, with $\beta_1 \neq \beta_2$.

Equation (5) can be estimated by OLS, since for given thresholds the model is linear in slopes. The determination of the estimated threshold, $\hat{\theta}$, is based on two steps procedure using ordinary least squares (OLS) method[5]. In the first step, for any given threshold, θ, the sum of square errors is computed separately. In the second step, by minimizing of the sum of squares of errors, $S_1(\theta)$, the estimated threshold value, $\hat{\theta}$ is obtained and the residual variance, $\hat{\sigma}^2$, is saved. To check whether the threshold is in fact statistically significant, the null hypothesis of no threshold effect is tested: $H_0 : \beta_1 = \beta_2$. The likelihood ratio test of H_0 is based on the following F-statistics: $F_1 = (S_0 - S_1(\hat{\theta}))/\hat{\sigma}^2$, where S_0 and $S_1(\hat{\theta})$ are sum of squared errors under null and alternative hypotheses, respectively. The asymptotic distribution of F_1 is non-standard. HANSEN (1999) propose to use a bootstrap procedure to compute the p-value for F_1 under H_0.

Furthermore, if the single threshold is indeed exists, we can extend the panel threshold regression model with single threshold to double double threshold model (three regimes) as follows:

$$p^m_{it} = \begin{cases} \alpha_i + \beta_1' x_{it} + \varepsilon_{it}, & \pi_{it} \leq \theta_1, \\ \alpha_i + \beta_2' x_{it} + \varepsilon_{it}, & \theta_1 < \pi_{it} \leq \theta_2, \\ \alpha_i + \beta_3' x_{it} + \varepsilon_{it}, & \theta_2 < \pi_{it}. \end{cases} \tag{6}$$

where threshold values $\theta_1 < \theta_2$.[6] The sum of squared residuals $S(\theta_1, \theta_2)$ can be calculated as in the single threshold model and the joint least squares estimates of (θ_1, θ_2) are the values which jointly minimize $S(\theta_1, \theta_2)$.

[4] In general, the threshold variable may be an element of x_{it} or a variable external to model. In our implementation of the threshold panel method, we consider inflation rate, π_{it}, as threshold variable, which are not belonging to explanatory variables of the pass-through equation.

[5] Estimation techniques for a single panel threshold model is given in the Appendix.

[6] We illustrate the methods for the double threshold model since these methods extend in straightforward way to higher order threshold models. Following the same procedure, we can go further to the ones with triple or multiple thresholds $(\theta_1, \theta_2, \theta_3, \ldots, \theta_n)$.

5 Empirical results

In order to determine the number of thresholds, we follow the bootstrap method proposed by HANSEN (1999) to obtain the approximations of the F statistics and then calculate the p-values. The F statistics contains F_1, F_2 and F_3 to assess the null hypotheses of none, one and two thresholds, respectively.[7] Once a single or more significant thresholds are found, we can estimate the pass-through coefficient for each regime. For the purpose of our analysis, we use the estimated threshold to divide our country sample into different groups with respect to their macroeconomic environment, namely the inflation regime.[8] Then, we estimate the ERPT elasticity for each class of countries in order to make a comparison between different groups.

Table 2 presents the empirical results of test for single threshold, double threshold, and triple threshold effects. We find that the test for a single threshold is highly significant with a bootstrap p-value of 0.01 and the test for a double threshold is also significant with a p-value of 0.03. However, the test statistic for a third threshold is far from being statistically significant with a p-value of 0.38. Therefore, the sequential test procedure implies two thresholds and, thus, three inflation regimes in our ERPT equation for the sample of 63 countries.

Table 2: HANSEN (1999) test for multiple thresholds

Threshold value	**F-statistics**	**p-value**	**5% critical value**
Single threshold effect test (H_0: no threshold):			
2.76	25.57	0.012	14.417
Double threshold effect test (H_0: at most one threshold):			
2.76	19.66	0.032	10.781
8.28			
Triple threshold effect test (H_0: at most two thresholds):			
2.76	5.46	0.383	8.635
8.28			
24.49			

Note: Table reports threshold estimates ($\hat{\theta}$), F-test of the null hypothesis of no threshold effect and bootstrapped p-values obtained from 1000 bootstrap replications.

Table 2 also presents the estimated values of two thresholds $(\hat{\theta}_1, \hat{\theta}_2)$, which are 2.76% and 8.28% of inflation rates, respectively. Thus, all observations will be objectively split into three regimes depending on whether the threshold variable, i.e. inflation rate is smaller or larger than the threshold value (θ_1, θ_2). Accordingly, we define three inflation regimes: *low inflation* regime including

[7] The bootstrap procedure is repeated 1000 times for each of the three panel threshold tests.

[8] We follow the same strategy of HANSEN (1999) who used the threshold values to split his sample of 565 US firms into *low debt* and *high debt* firms.

countries with mean annual inflation rates less than 2.76%, *moderate inflation* regime for those with inflation levels between 2.76% and 8.28%, and *high inflation* regime comprising countries with annual mean inflation exceeding 8.28%. According to this classification, we obtain 18 *low inflation* countries, 24 countries with *moderate inflation* levels and 21 *high inflation* countries (see Table 2).

Table 3: Country Classification

Low inflation countries ($\pi_{it} < 2.76\%$)		**Moderate inflation countries** ($2.76\% < \pi_{it} < 8.28\%$)		**High inflation countries** ($8.28\% < \pi_{it}$)	
Austria	Norway	Australia	Jordan	Algeria	Nigeria
Belgium	Singapore	Bolivia	Korea	Argentina	Pakistan
Canada	Sweden	Burkina Faso	Morocco	Botswana	Paraguay
Denmark	Switzerland	Chile	Philippines	Brazil	Poland
Finland	United	China	Portugal	Bulgaria	Romania
France	Kingdom	Côte d'Ivoire	Senegal	Colombia	Turkey
Germany	United	Czech	Slovak	Costa Rica	Uruguay
Ireland	States	Republic	Republic	Ecuador	Venezuela
Luxembourg		Gabon	Slovenia	Hungary	Zambia
Japan		Greece	South Africa	Indonesia	
Netherlands		Iceland	Spain	Iran	
New Zealand		India	Thailand	Mexico	
		Italy	Tunisia		
18 countries		**24 Countries**		**21 Countries**	

Note: Low inflation countries are defined as countries with less than 2.76% of inflation rate. Moderate inflation countries are those with inflation rates between 2.76% and 8.28%. Higher inflation countries are those having more than 8.28% of inflation rate. Last line denotes number of countries in each class.

Once we split our sample into three regimes, we can estimate the ERPT elasticity for each class of countries in order to make a comparison between different groups. This enables to draw conclusion about the link between the extent of pass-through and the inflation environment. Estimates of ERPT for each group of countries reported in Table 4. In view of results, *low inflation* countries experience import prices elasticity equal to 0.47%. While one percent exchange rate depreciation causes an increase in import prices by 0.66% for *moderate inflation* countries. Concerning the high inflation countries, the ERPT coefficient is close to unity, with import prices sensibility equals to 0.93%. It is evident that this finding corroborates the convention wisdom of the positive link between Inflation and pass-through (TAYLOR, 2000). That is, countries with higher rates of inflation should have higher rates of pass-through of exchange rates into import prices. Our results provide an evidence of regime-dependence of ERPT with respect to inflation environment and this latter would be an important source of heterogeneity in pass-through across countries.

In his sample of 24 developing countries, BARHOUMI (2006) found that countries characterized by high inflation regimes experience a higher long-run exchange rate pass-through into import prices than lower inflation regimes, which corroborates our estimation results. The main difference with our study is that we provide a panel threshold model giving more accurate thresholds to split countries. Our result are in line with recent empirical literature which uses nonlinear time series when measuring the extent of pass-through. Using smooth transition regression framework, SHINTANI, TERADA-HAGIWARA, and TOMOYOSHI (2013) and BEN CHEIKH (2012) have found strong evidence for the regime dependence of ERPT to inflation regime. Nonetheless, our approach is still different from the mentioned studies since, on the one hand, we take into account the cross-section dimension additionally to the time series dimension, and on the other hand, our framework considers a threshold regression where the transition across regimes is rather abrupt.

Table 4: Estimation of ERPT equation for different inflation regimes

	Dependent Variable: Δp_{it}^m		
	Low inflation countries	**Moderate inflation countries**	**High inflation countries**
Δe_{it}	0.47**	0.66**	0.93**
	[0,42 ∣ 0,53]	[0,57 ∣ 0,71]	[0,87 ∣ 0,98]
	(2.91)	(3.25)	(4.86)
Δy_{it}	0.17*	0.05	0.21**
	(1.71)	(1.25)	(2.86)
Δw_{it}^*	0.88**	0.61**	0.51**
	(3.15)	(7.40)	(10.66)

Note: *,** and *** denote significance at the 10%, 5%, 1% level respectively. For ERPT elasticities, 95% confidence intervals are reported between square brackets. p-values are in parentheses.

6 Conclusion

In this paper, we use a new approach to throw light on the role of inflation regime in explaining the extent of the exchange rate pass-through (ERPT) into import prices. In order to classify his sample of 24 developing countries by regimes of inflation, BARHOUMI (2006) chose an arbitrary threshold of 10% to split sample between high and low inflation regimes. For more accuracy, our study proposes to use a panel threshold framework where a grid search is used to select the appropriate threshold value. In a larger panel-data set including 63 countries over the period 1992-2012, we find that there are two thresholds points that are well identified by the data, allowing us to split our sample into three inflation regimes. When estimating the ERPT for each group of countries, we point out a strong regime-dependence of pass-through to inflation environment, that is, the class of countries with higher inflation rates experience the higher degree of ERPT.

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Appendix. Panel Threshold Model: HANSEN (1999)

Equation (6) in the text can be written as follows:

$$y_{it} = \alpha_i + \beta' x_{it}(\theta) + \varepsilon_{it}, \tag{7}$$

where y_{it} is the dependent variable, $x_{it}(\theta) = \begin{pmatrix} x_{it} I(q_{it} \leq \theta) \\ x_{it} I(q_{it} > \theta) \end{pmatrix}$ is a k-dimensional vector of exogenous variables and $\beta = (\beta_1', \beta_2')$.

After removing the individual-specific means, α_i, using the within transformation estimation techniques, the OLS estimator of β is given by:

$$\hat{\beta}(\theta) = (X^*(\theta)' X^*(\theta))^{-1} X^*(\theta)' Y^* \tag{8}$$

where X^* and Y^* denote the stacked data over all individuals after removing the individual specific means.

The vector of regression residuals is $\hat{\varepsilon}^*(\theta) = Y^* - X^*(\theta)\hat{\beta}(\theta)$ and the sum of squared errors can be written as

$$S_1(\theta) = \hat{\varepsilon}^*(\theta)' \hat{\varepsilon}^*(\theta) = Y^{*'} \left(I - X^*(\theta)' (X^*(\theta)' X^*(\theta))^{-1} X^*(\theta)'\right) Y^* \tag{9}$$

In a second step HANSEN (1999) recommend the estimation of the threshold θ by least squares which is achieved by minimization of the concentrated sum of squared errors $S_1(\theta)$. Then, the least squares estimators of $\hat{\theta}$ is given by

$$\hat{\theta} = \underset{\theta}{\operatorname{argmin}}\, S_1(\theta) \tag{10}$$

Hence, the resulting estimate for the slope coefficient is obtained by $\hat{\beta} = \hat{\beta}(\hat{\theta})$. The residual vector is $\hat{\varepsilon}^* = \hat{\varepsilon}^*(\hat{\theta})$ and residual variance is defined as:

$$\hat{\sigma}^2 = \frac{1}{N(T-1)} \hat{\varepsilon}^{*'} \hat{\varepsilon}^* = \frac{1}{N(T-1)} S_1(\hat{\theta}) \tag{11}$$