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Empirical analysis of the Dornbursch’s exchange rate overshooting hypothesis:

an application to commodity currency countries

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Abstract

This master thesis will try to analyse the behaviour of the exchange rate following an exogenous shock. As an addition to the classical exchange rate regression equation used in the literature, we will add an additional exogenous variable to the regression, namely the commodity price index, justified by the countries of analysis chosen: Canada, Chile and Mexico. The purpose is to see if the overshooting phenomenon described by Dornbusch (1976) holds after an exogenous shock or not, meaning if the exchange rate shows a stronger reaction in short-term than its long-run equilibrium. To do so, two econometric approaches will be used, the Local Projection (LP) and the Autoregressive-Distributed Lag (ARDL), and comparisons of the results will be done. One important result obtained from the two approaches is that following an commodity price shock, there is no overshooting of the exchange rate observed.

Keywords— Exchange rate, Overshooting, Commodity currency, Local Projection, ARDL

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Contents

1 Introduction

This master thesis will try to understand if the overshooting phenomenon holds as explained by Dornbusch (1976) in the case where the country of analysis have a commodity currency. For the purpose of this analysis, a modified exchange rate regression equation will be developed which add a new variable relative to the commodity price in the exchange rate regression. In addition to study overshooting of the exchange rate after a monetary shock or an interest rate shock, we will also consider check if overshooting occurs after an exogenous commodity price shock.

Previous authors have studied the overshooting phenomenon described by Dornbusch (1976). As an example, the analysis performed by Bahmani-Oskooee and Kara (2000) checks if following an exogenous shock, namely a monetary or foreign interest rate shock, the exchange rate reacts more strongly in the short-term than in the long-term. These analysis does not take into account any other type of exogenous shock that could modify the exchange rate.

Chen and Rogoff (2003) introduced the concept of commodity currency. Countries whose exports are highly concentrated on primary commodities have an exchange rate sensible to the change in price of those commodities. According to Chen and Rogoff (2003), as change in the commodity price impacts the term-of-trades of these countries, variation of the exchange rate occurs. The three countries of analysis, Canada, Mexico and Chile have a large part of their exports composed by primary commodities. Their exchange rate should react to change in the commodity price.

For countries having an exchange rate highly influenced by the primary commodity price, we do not know if the overshooting phenomenon occurs following the commodity price shock. The following master thesis will try to identify the response of the exchange rate due to an exogenous shock, namely monetary expansion, commodity price increase and negative foreign interest rate shock. The purpose is to check if the Dornbusch's hypothesis holds. If the shock causes the exchange rate to have a stronger reaction in short-term than in the long-term, the overshooting holds.

To check empirically the overshooting phenomenon, two econometric approaches will be used. The first econometric approach is the Autoregressive-Distributed Lag with Unrestricted Error Correction Model (ARDL-UECM) by Pesaran, Shin and Smith (1998) and the second one the Local Projection by Jorda (2005). Many previous studies have analysed the overshooting phenomenon by using the ARDL-UECM as an error correction model that contains the advantage to distinguish the short and long-term effect. Nieh and Wang (2005) conclude overshooting phenomenon exist for Taiwan and Bahmani-Oskooee and Kara (2000) conclude its existence for the Turkish Lira.

The second econometric approach, the Local Projection (LP), is a new econometrics approach developed by Jorda (2005), widely used in the monetary literature. Iacoviello and Navarro (2018) used the LP to measure the impact of U.S. monetary shock on foreign economies. Müller, Wolf and Hettig (2019) estimate the effet of monetary shocks on the exchange rate of the U.S. dollar.

2 Commodity currency

Commodity currencies are currency whose exchange rate is influenced by the price of primary commodity. As primary commodities constitute a high part of the country's exportation, an increase in the price of the commodity exported generates a gain in revenue for the country. As the term-of-trade increases, its exchange rate with respect to foreign countries appreciates. The analysis will be focused on three countries, Canada, Chile and Mexico. These three countries have commodity currency as their exports are highly composed by primary commodities.

Gruss and Kebhaj (2019) reconstructed an index for each country representing this term-of-trade. To obtain the index, they take into consideration 45 international commodity prices. Each price is weighted with respect to the share of the net export of the commodity in the output. Two versions of the index are available, fixed weights and time-varying weights, the latter does take into account the change in the trade over the time and will be used in the analysis.

One purpose of the next sections will be to see what is the impact of changes in the index, namely whether there is a gain or lose of income when the price of the commodities changes. Robustness check will be conducted with an alternative index where each price is weighted with respect to the share of the export of the commodity in the output.

3 Monetary model

In this section, we will derive a regression model of exchange rate determination derived from the monetary model based on the presentation made by Bahmani-Oskooee and Kara (2000). In order to obtain it, we will use known economic relationships as the Purshasing Parity Power (PPP) and the Quantity theory of Money. This modified equation for the exchange rate will take into account change in the primary commodity prices. The objective is to use the regression equation obtained in this section to derive the equation of the econometric approaches in the next sections.

First, the Purshasing Parity Power (PPP) is defined as

$$E = \frac{P_n}{P_f} \tag{1}$$

where E is the exchange rate, P_n the national overall price index and P_f the foreign overall price index.

Secondly, the quantity theory of money can be defined separately in the two countries, $M_n V_n = P_n Y_n$ where M_n is the national money supply, V_n the national velocity, Y_n the national GDP and $M_f V_f = P_f Y_f$ the same expression for the foreign country.

Combining the PPP and the quantity theory of money equations we obtain,

$$E = \frac{M_n}{M_f} \frac{V_n}{V_f} \frac{Y_f}{Y_n} \tag{2}$$

If we use the log transformation of the previous equation 2 we can obtain the following regression equation

$$e_t = \beta_0 + \beta_1 m_t + \beta_2 y_t + \beta_v velocity_t + \epsilon_t \tag{3}$$

where $m_t = log(M_n) - log(M_f)$, $y_t = log(Y_n) - log(Y_f)$ and $velocity_t = log(V_n) - log(V_f)$. Following equation 2, β_1 and β_v should be positive and β_2 negative. It means that an increase in the national money supply or the national velocity should depreciate the exchange rate. An increase in the national GDP should appreciate the exchange rate.

To obtain the final exchange rate equation, we assume that three elements decrease the velocity, namely the interest rate differential $r_t = R_n - R_f$ the difference between the national and the foreign interest rate, the inflation differential $\pi_t = \pi_n - \pi_f$ the difference between the national and the foreign inflation and the log commodity price index cp_t. By an increase of one of these three variables, the demand of money should decrease, the reason being is an increase in the cost of holding money. If we consider a specific commodity price increase, holding money instead of the commodity is more costly.

The final regression equation is then obtained by replacing $velocity_t$ by the three elements that influence it namely r_t, π_t and cp_t.

$$e_t = \beta_0 + \beta_1 m_t + \beta_2 y_t + \beta_3 r_t + \beta_4 \pi_t + \beta_5 cp_t + \epsilon_t \tag{4}$$

where $\beta_{3,4,5}$ are expected to be negative [1]. The regression equation 4, a long-run relationship of the exchange rate, will be used in the next sections to derive the equations of the ARDL and the LP. These two econometric approaches will help to determine if the overshooting phenomenon holds after an exogenous shock.

[1]This result is also coherent with the Uncovered Interest rate Parity (UIP)

4 Data description

4.1 Sources

The database used has been retrieved from the website of the OECD and is composed of the time series of Chile, Canada, Mexico and the United States. The time series are monthly and covers the period [Jan 2005:Dec 2018] for a total of 168 periods except for Mexico that has 158 periods [Jan 2005:Feb 2018].

It is composed of the time series for the industrial production as a proxy for the GDP, the inflation rate, broad (M3) money [2] and finally the short-term interest rate based on three-month treasury bill rate.

The exchange rate has been retrieved from the website of the St.Louis FED. It contains the national currency to USD exchange rate (in french "à l'incertain"). More precisely, it is expressed monthly and it is an average of daily rates. It covers the following period [Jan 2005:Dec 2018].

The commodity price index is from the IMF and is constructed by Gruss and Kebhaj (2019). They cover the following period [Jan 2005:Dec 2018].

4.2 Time series description

The graphs of this section represents the time series used in the models in the next sections. All variables are relative to the U.S. except the commodity price variable[3]. They represents the log exchange rate, the log relative GDP, the log relative money supply, the inflation differential, the interest rate differential and the log commodity price index.

Figure 1 shows the evolution of all variables across the period of the analysis, from January 2005 to December 2018 for Canada. The log exchange rate appreciates from 2005 to 2012 and then depreciates from 2012 to 2018. The log relative GDP decrease from 2005 to 2009 to remain stable until 2018. The log relative money supply increases across time. From 2005 to 2012 the inflation differential is volatile but stable across time. The interest rate differential increases from 2006 to 2010 to remain at its highest level until 2014 where there is a decrease. The log commodity price index is almost constant across time but volatile with peaks.

Figure 2 shows the evolution across time of the variables for Chile. As Canada, the Chilean log exchange rate appreciates first and then depreciates. The log relative GDP increases from 2005 to 2009 to remain stable after that period.[4] Over time, the log relative money supply increases. The inflation differential is relatively stable except some peaks between 2008 and 2010. The interest rate differential peaks around 2009 and increases on 2011. It decreases slowly until 2018. The log commodity price index is almost constant across time but volatile with peaks.

[2] Using broad money instead of narrow (M1) money provides better results

[3] As the index is already "divided by the IMF's unit value index for manufactured exports", this index will not be differentiated by the U.S index

[4] According to the IMF report on Chile, the drop in February 2010 is due to an earthquake.

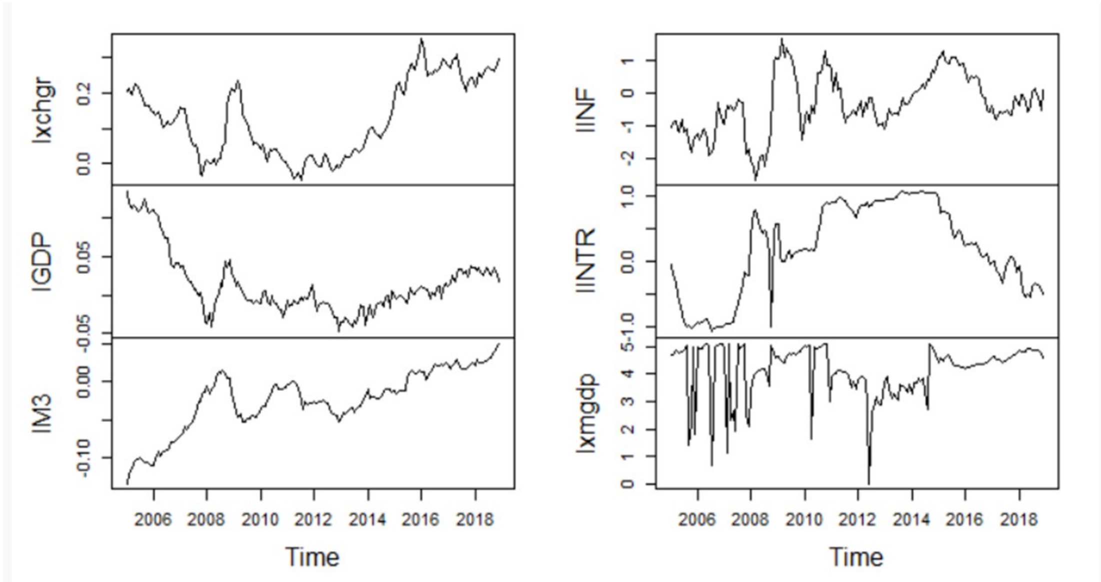


Figure 1: Evolution of the variables from January 2005 to December 2018 for Canada

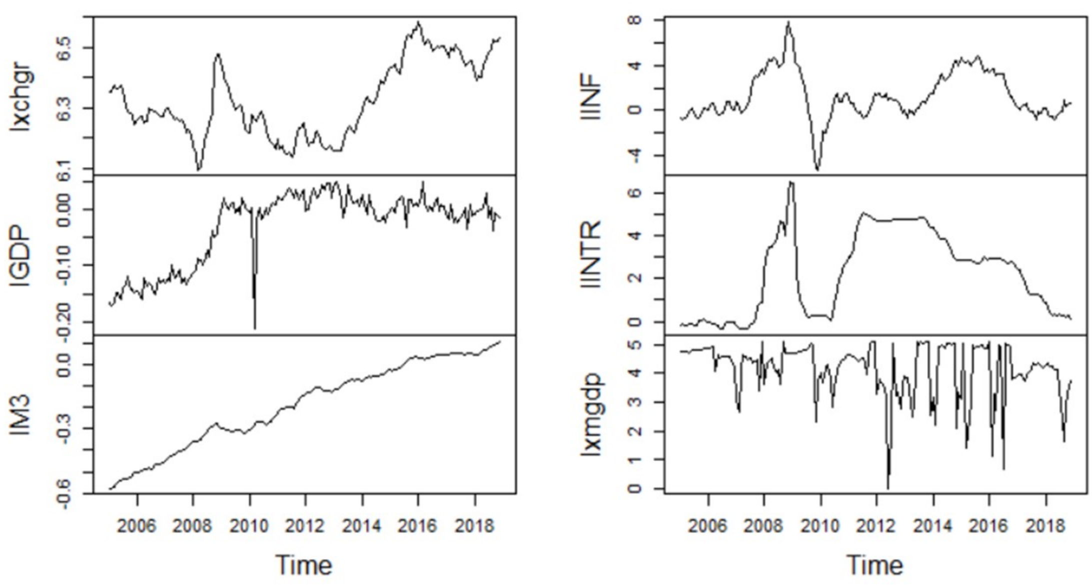


Figure 2: Evolution of the variables from January 2005 to December 2018 for Chile

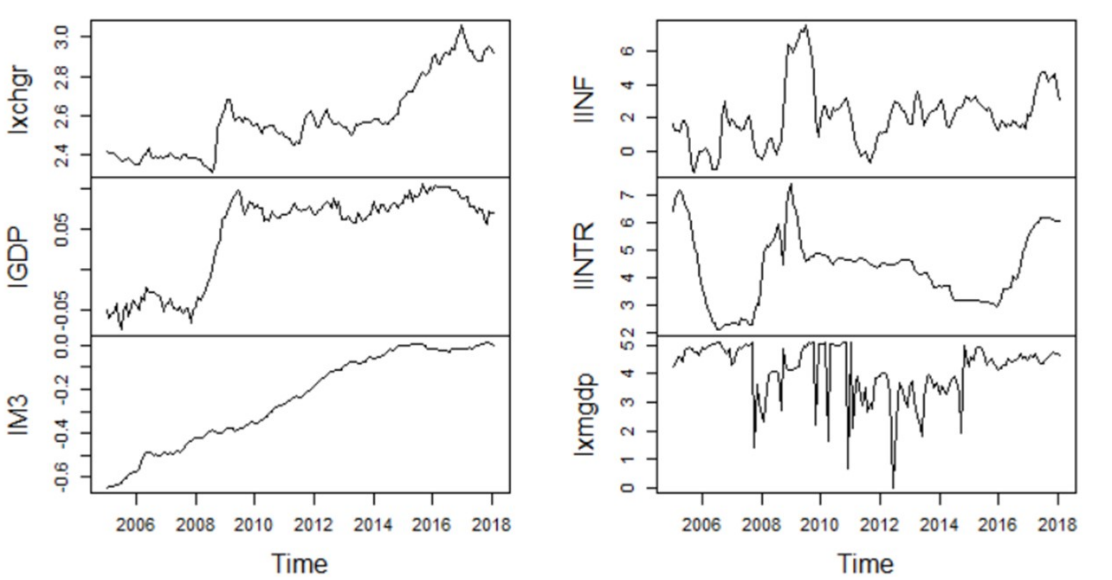


Figure 3: Evolution of the variables from January 2005 to February 2018 for Mexico

Figure 3 shows the evolution across time of the variables for Mexico. The log exchange rate depreciates over time. The log relative GDP is stable from 2005 to 2008 and increase in 2008 to remain to stable until 2018. The log relative money supply increases over time. The inflation differential is volatile but relatively stable from 2005 to 2018. Even if the interest rate differential is relatively stable from 2010 to 2016, it is more volatile before 2010. Similarly to Canada and Chile, the log commodity price index is almost constant across time but volatile with peaks.

5 Autoregressive-Distributed Lag with Unrestricted Error Correction Model

Dornbursch (1976) considers the overshooting is a short-term phenomena. As an exogenous shock occurs, the short-term effect on the exchange rate is more important than its long-term level. This economic separation of the short-term and long-term follows the idea of econometric models using Error Correction. As a consequence, several authors (Bahmani-Oskooee and Panthamit(2006), Niew and Wang (2005), Bahmani-Oskooee and Kara (2000)) used the Autoregressive Distributed Lag model (ARDL) with Error Correction.

5.1 Degree of integration

To avoid spurious regressions, we generally insure that our regression does not contain variables that are not stationary. That said, Pesaran and al. (1998) insures that the long-term relationship of the ARDL model produce consistent estimator whether we have I(1) or I(0) variables in level. Moreover, knowledge about the degree of integration gives indication about how to use the bound test in the next section.[5]. One additional information that is important for the use of ARDL model is to know if there is some ambiguity about the degree of integration of some variables relative to the result of the test made. To check this ambiguity relative to the degree of integration, two tests have been chosen: Augmented Dickey–Fuller (ADF) test and the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test. The ADF test has as an alternative hypothesis that the variable is stationary when on the other side the KPSS informs about the stationarity of a variable when the null hypothesis is not rejected.

Table 1,2 and 3 contain the result of the two tests, ADF and KPSS, to determine the degree of integration for the three countries of analysis.

For Canada, the degree of integration of the inflation in level is I(0). That said, the KPSS gives as a result I(1). The commodity price (CP) is I(0) in the two tests. The other variables are all I(1) in level in the two tests.

In the case of Chile, the result concerning inflation (π) gives, following the two test, a degree of integration I(0). Concerning the commodity price (CP), the KPSS indicates that the variable have a degree of integration I(1) but the ADF test suggests I(0). The other variables are I(1) in level.

[5]More detail in the Section Bound F-test and t-test for cointegration

Table 1: Degree of integration tests for Canada

Canada

Variable	ADF						KPSS					
	Level		Decision	Difference		Decision	Level		Decision	Difference		Decision
E	-2,4		I(1)	-4,77	***	I(0)	1,24	***	I(1)	0,23		I(0)
Y	-2,39		I(1)	-4,84	***	I(0)	1,09	***	I(1)	0,45	*	I(0)
M	-2,47		I(1)	-4,57	***	I(0)	2,28	***	I(1)	0,15		I(0)
π	-4,02	***	I(0)	-4,39	***	I(0)	0,84	***	I(1)	0,03		I(0)
I	-0,96		I(1)	-5,28	***	I(0)	1,16	***	I(1)	0,21		I(0)
CP	-3,85	**	I(0)	-10,45	***	I(0)	0,32		I(0)	0,02		I(0)

ADF test: Significant at 1 percent -3.99, 5 percent -3.43, 10 percent -3.13

KPSS test: Significant at 1 percent 0.739, 5 percent 0.463, 10 percent 0.347

*Significant at 10 percent, **Significant at 5 percent, *** Significant at 1 percent

I(0) Degree of integration 0, I(1) Degree of integration 1

Table 2: Degree of integration tests for Chile

Chile

Variable	ADF						KPSS					
	Level		Decision	Difference		Decision	Level		Decision	Difference		Decision
E	-2.42		I(1)	-4.94	***	I(0)	2.14	***	I(1)	0.27		I(0)
Y	-1.95		I(1)	-5.53	***	I(0)	2.27	***	I(1)	0.08		I(0)
M	-1.99		I(1)	-5.13	***	I(0)	3.4	***	I(1)	0.25		I(0)
π	-3.43	**	I(0)	-4.45	***	I(0)	0.15		I(0)	0.04		I(0)
I	-2.21		I(1)	-4.47	***	I(0)	0.67	**	I(1)	0.17		I(0)
CP	-5.62	***	I(0)	-7.28	***	I(0)	0.59	**	I(1)	0.01		I(0)

ADF test: Significant at 1 percent -3.99, 5 percent -3.43, 10 percent -3.13

KPSS test: Significant at 1 percent 0.739, 5 percent 0.463, 10 percent 0.347

*Significant at 10 percent, **Significant at 5 percent, *** Significant at 1 percent

I(0) Degree of integration 0, I(1) Degree of integration 1

Table 3: Degree of integration tests for Mexico

Mexico

Variable	ADF						KPSS					
	Level		Decision	Difference		Decision	Level		Decision	Difference		Decision
E	-2,43		I(1)	-5,48	***	I(0)	2,56	***	I(1)	0,09		I(0)
Y	-1,9		I(1)	-3,51	**	I(0)	2,36	***	I(1)	0,24		I(0)
M	-0,52		I(1)	-4,51	***	I(0)	3,19	***	I(1)	0,65	**	I(0)
π	-3,26	*	I(0)	-4,93	***	I(0)	0,43	*	I(1)	0,03		I(0)
I	-2,8		I(1)	-4	***	I(0)	0,13		I(0)	0,2		I(0)
CP	-2,73		I(1)	-7,09	***	I(0)	0,47	**	I(1)	0,02		I(0)

ADF test: Significant at 1 percent -3.99, 5 percent -3.43, 10 percent -3.13

KPSS test: Significant at 1 percent 0.739, 5 percent 0.463, 10 percent 0.347

*Significant at 10 percent, **Significant at 5 percent, *** Significant at 1 percent

I(0) Degree of integration 0, I(1) Degree of integration 1

For Mexico, the variable inflation in level has a degree of integration I(0) with the ADF test but not with the KPSS test. On the other side, the variable interest rate in level has a degree of integration I(0) with the KPSS test only. The other variables are I(1) in level and their first difference is I(0).

5.2 Model

Following the equation 4, we can write the following ARDL$(n_1, n_2, n_3, n_4, n_5, n_6)$[6] model.

$$\Delta e_t = c_0 + \Sigma_{j=1}^{n_1-1} b_j \Delta e_{t-j} + \Sigma_{j=0}^{n_2-1} c_j \Delta m_{t-j} + \Sigma_{j=0}^{n_3-1} d_j \Delta y_{t-j} + \Sigma_{j=0}^{n_4-1} f_j \Delta r_{t-j} + \Sigma_{j=0}^{n_5-1} g_j \Delta \pi_{t-j} + \Sigma_{j=0}^{n_6-1} h_j \Delta cp_{t-j}$$
$$+\phi_1 e_{t-1} + \phi_2 m_{t-1} + \phi_3 y_{t-1} + \phi_4 r_{t-1} + \phi_5 \pi_{t-1} + \phi_6 cp_{t-1} + \epsilon_t \quad (5)$$

where e_t the exchange rate, c_0 a constant, m_t the log relative money supply M_3, y_t the log difference GDP, r_t nominal interest rate differential, π_t the relative inflation rate, cp the log commodity index and ϵ_t is the error term.

The long-term relationship of equation 5 can be rewritten as follow

$$e = \gamma_0 + \gamma_2 m + \gamma_3 y + \gamma_4 r + \gamma_5 \pi + \gamma_6 cp \quad (6)$$

where $\gamma_i = -(\phi_i/\phi_1)$ for every i.

5.3 Bound F-test and t-test for cointegration

To check the long-run relationship, the Bound F-test and t-test by Pesaran and al. (2001) are used. These tests inform if there is or not cointegration. The Bound F-test and t-test are not regular tests.

In statistics, variables with degree of integration I(1) are cointegrated if there exist a linear combination between the variables such that this linear combination is I(0). According to Pesaran and al. (1998), the ARDL model produces consistent long-run estimators whether the variables are I(0) or I(1).

These tests have a lower and upper bound representing two extreme cases. The lower bound considers that all variables of the ARDL model are I(0) and the upper that all variables are I(1).

The F-test and t-test have been designed for the special case where we don't know with certainty the degree of integration (meaning that the degree of integration of a variable differs in the ADF and KPSS tests). This incertainty is present for the three countries for at least one variable each time.[7] It is then coherent to consider these upper and lower bounds.

If we report the lower and upper bound of the F-test[8] and the t-test[9], we have respectively [2.26;3.35] and [-2.57;-3.86] for $\alpha = 0.1$. The F-test have as a null hypothesis that, from equation 5, $\forall_i \ \phi_i = 0$ versus $\phi_i \neq 0$, for at least one i. The t-test check only if the Error Correction term $\phi_1 = 0$ versus $\phi_1 \neq 0$.

According to Pesaran and al. (2001), we can conclude that there exist a cointegration relationship if the critical value is above the upper bound. Falling between the upper and lower bound does not let us conclude

[6]The lags that been manually adjusted to obtain the best regression as the AIC did not provide result with significant coefficient and a cointegration

[7]See the section Degree of integration

[8]See page 300 of Pesaran and al. (2001) Case III: Unrestricted intercept and no trend

[9]See page 303 of Pesaran and al. (2001) Case III: Unrestricted intercept and no trend

that a cointegration relationship exist neither reject its existence. We reject the existence of a long-run relationship if the critical value is lower than the lower bound.

Table 4: Bound Test for cointegration

	F-test	T-test
$\alpha = 0.1$	Lower B.:2.26 / Upper B.: 3.35	Lower B.:-2.57 / Upper B.: -3.86
Canada	3.96	-3
Chile	4.23	-3.21
Mexico	2.68	-3.51

On Table 4, the F-test gives evidence of cointegration for Canada and Chile. Their critical values, respectively 3.96 and 4.23, are above the upper bound for a level of significance of $\alpha = 0.1$. Their t-test falls between the bounds giving some uncertainty about the existence of the cointegration relationship.

For Mexico, the F-test and t-test critical values, respectively 2.68 and -3.51, are between the two bounds. There is uncertainty about the existence of the long-run relationship without being able to reject it.

5.4 Result

This section will analyse impulse responses generated with the equation 5.[10] Three criteria to determine if there is overshooting or not will be taken into account during the analysis: the significance of the coefficients in the equation 5 related to shock analysed, the significance in the coefficient in the equation 6 and finally the impulse response. The impulse response have been constructed following a shock bringing the exogenous variable m from $ln(100)$ to $ln(101)$, cp from $ln(100)$ to $ln(200)$ and the exogenous variable r from 1 percent to 2 percent.

Estimates of equation 6 are reported in table 5. Concerning the coefficients we are interest in the analysis, the long-run equation contains significant and positive coefficient for the money supply where on the other side the commodity price coefficient is only significant with a positive sign for Mexico. Non of the interest rate coefficient are significant at $\alpha = 0.1$ and have except for Mexico a negative sign. Concerning other coefficients of the long-run relationship, the relative GDP is only significant and negative for Chile. Chile is also the only country to have a significant inflation coefficient. The intercept of Chile and Mexico are highly significant.

Estimates of equation 5 are reported in tables 7, 8 and 9 in the appendix. If we analyse the number of significant coefficients, we notice that Mexico have only 12 significant coefficients out of 27 where Canada and Chile have respectively 14 out of 28 and 19 out 32 significant coefficients at $\alpha = 0.1$.

Concerning the goodness-of-fit of the models, we can report for Canada and Chile respectively an adjusted R-squared of 0.44 and 0.43[11]. Mexico has an adjusted R-squared of 0.20 which is approximately twice less than the two other countries. The in-sample forecast realised shows that the models predicts quite well the actual log exchange rate with a Root Mean Square Error[12] of 0.0139 for Canada, 0.01784 for Chile and 0.02225 for Mexico. The quality of the regression is much better for Canada and Chile following the goodness-of-fit measures.

[10] The graphs does not contain confidence interval. This is a lack in the analysis.

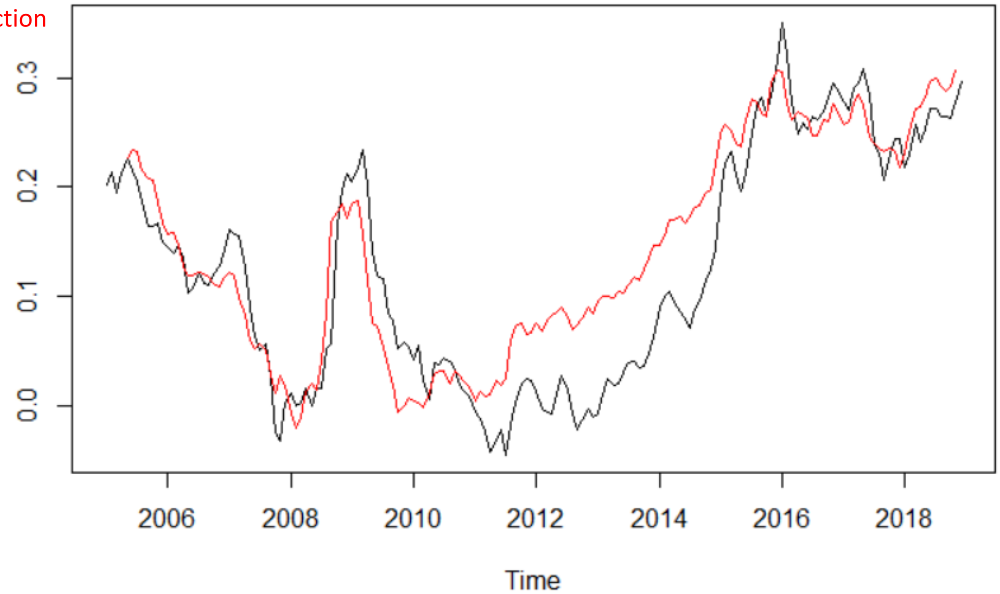
[11] As a comparaison, the paper of Bahmani-Oskooee and Panthamit (2006) estimates multiple ARDL model to analyse the overshooting of some East Asian countries and have an adjusted R-squared between 0.25 and 0.35 approximately.

[12] As the Root Mean Square Error has the scale of the dependant variable and is a measure of how well the model can predict this dependant variable Δe_t, it is useful to give the minimum and maximum of Δe_t to know how important the RMSE is. Canada [-0.062,0.109], Chile [-0.075;0.162], Mexico [-0.088 ,0.172].

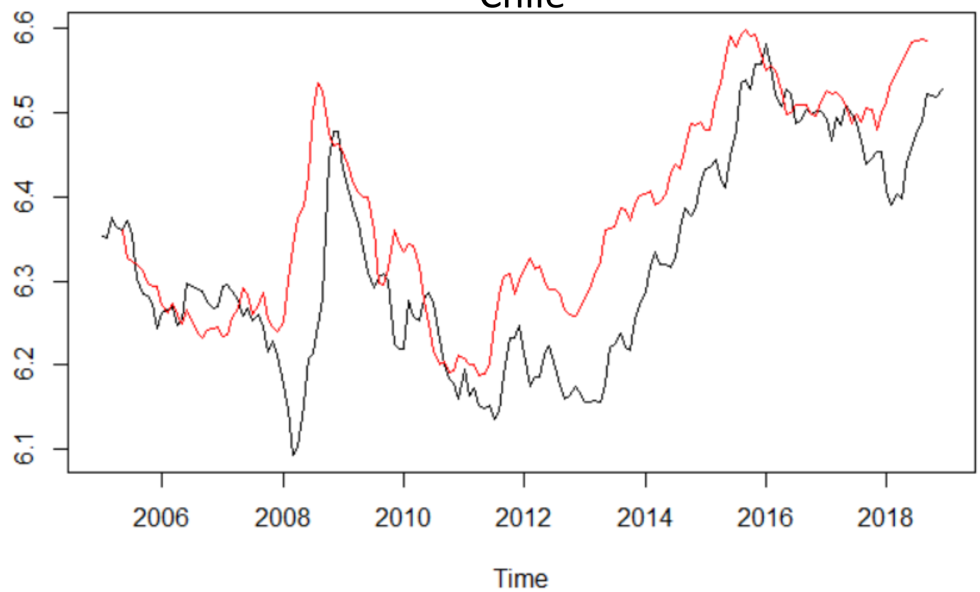
In-Sample forecast

Black: Log exchange rate data
Red: Model Prediction

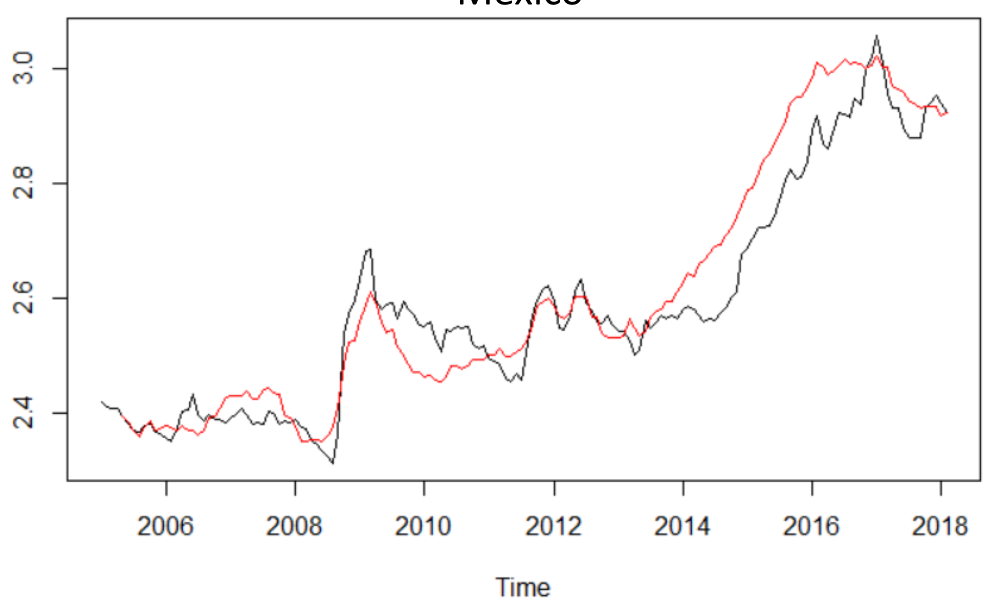
Canada

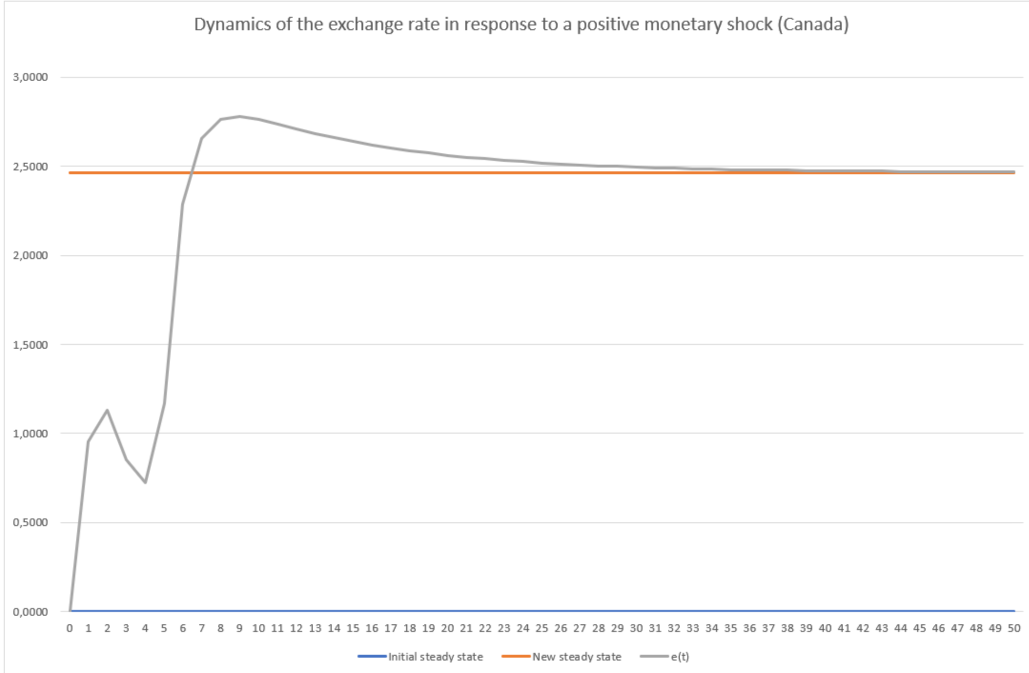


Chile

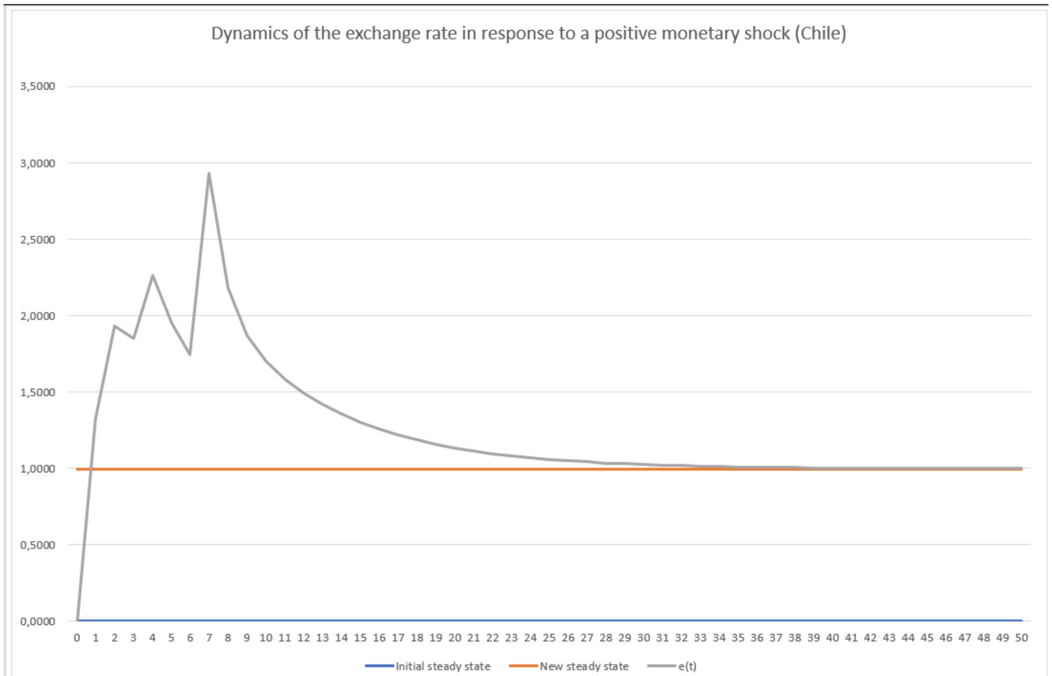


Mexico

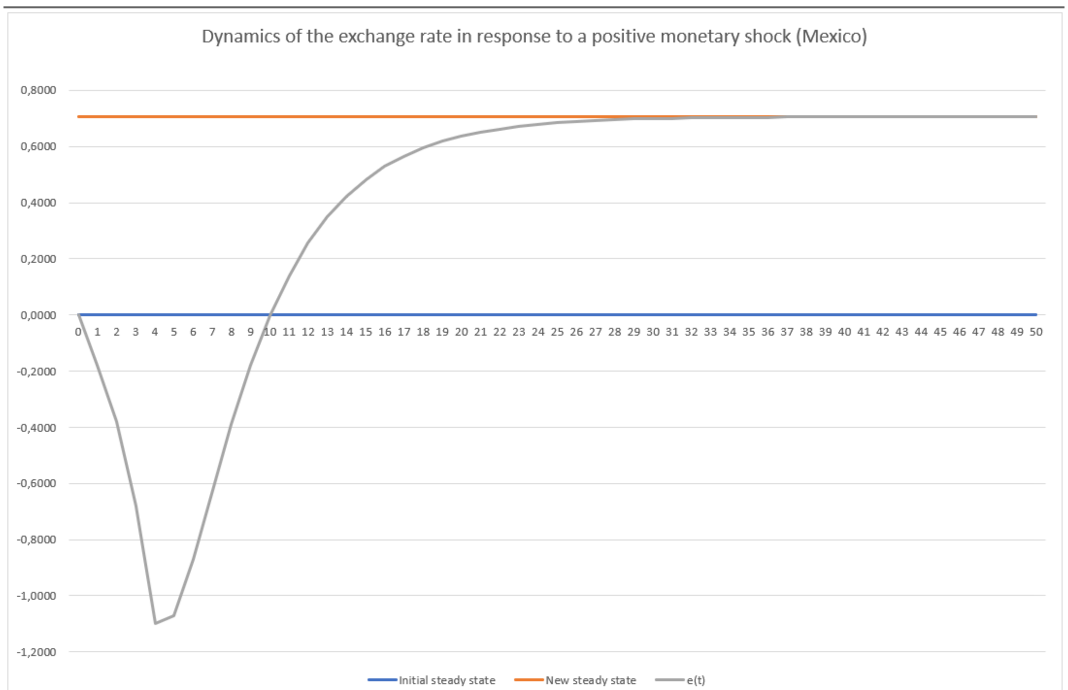




Dynamics of the exchange rate in response to a positive monetary shock (Canada)



Dynamics of the exchange rate in response to a positive monetary shock (Chile)



Dynamics of the exchange rate in response to a positive monetary shock (Mexico)

Table 5: Long-run relationship with t-statistics

	Canada	Chile	Mexico
Intercept	**0.25**	**6.23*** **	**2.2*** **
	1.21	*57.44*	*13.95*
y	**0.61**	**-1.75** **	**0.9**
	0.55	*-2.16*	*1.18*
m	**2.47*** **	**1*** **	**0.7*** **
	3.52	*4.9*	*3.76*
π	**0.0001**	**0.03*** **	**-0.02**
	0.0046	*2.78*	*-1.5*
r	**-0.0085**	**-0.007**	**0.024**
	-0.1425	*-0.4*	*1.26*
cp	**-0.024**	**0.028**	**0.12*** **
	-0.51	*1.31*	*4.11*

*Significant at 10 percent

**Significant at 5 percent

*** Significant at 1 percent

5.4.1 Positive Monetary shock

After a positive money supply shock making the relative money supply increases by 1 percent, the impulse response of the exchange rate for Canada shows a depreciation in the short and in the long-term. Three out of five short-term coefficients of the money supply are significant at $\alpha = 0.1$. The estimation of the significant long-run coefficient is 2.47. It means that an increase of 1 percent of the relative money supply makes the exchange rate depreciate by 2.47 percent in the long-run. This increase of the relative money supply depreciates after 8 months the exchange rate by 2.75 percent.

Chile's impulse response shows a depreciation of 3 percent in the short-term after the increase of the relative money supply. Among all short-term coefficients of the money supply, three are significant and five non-significant. Its long-run coefficient is also significant at $\alpha = 0.1$. The long-run coefficient of money supply is 1 meaning that 1 percent increase of the relative money supply causes in the long-run 1 percent increase of the exchange rate.

For Mexico, the impulse response shows an appreciation of the exchange rate in the short-term. Following a 1 percent increase of the relative money supply, the exchange rate appreciates by 1 percent after 4 months. However, non of the short-term coefficients of money supply are significant. The long-run money supply coefficient is significant at $\alpha = 0.1$. In the long-run the Mexican peso depreciates by 0.7 percent after the increase of the relative money supply.

The overshooting phenomena takes place after a positive monetary shock in Canada and Chile, meaning that their short-term depreciation is stronger than their long-run one. Mexico is the only countries which have an appreciation of the exchange rate in the short-run. As Canada and Chile, in the long-run, the Mexican peso depreciates after a positive monetary shock.

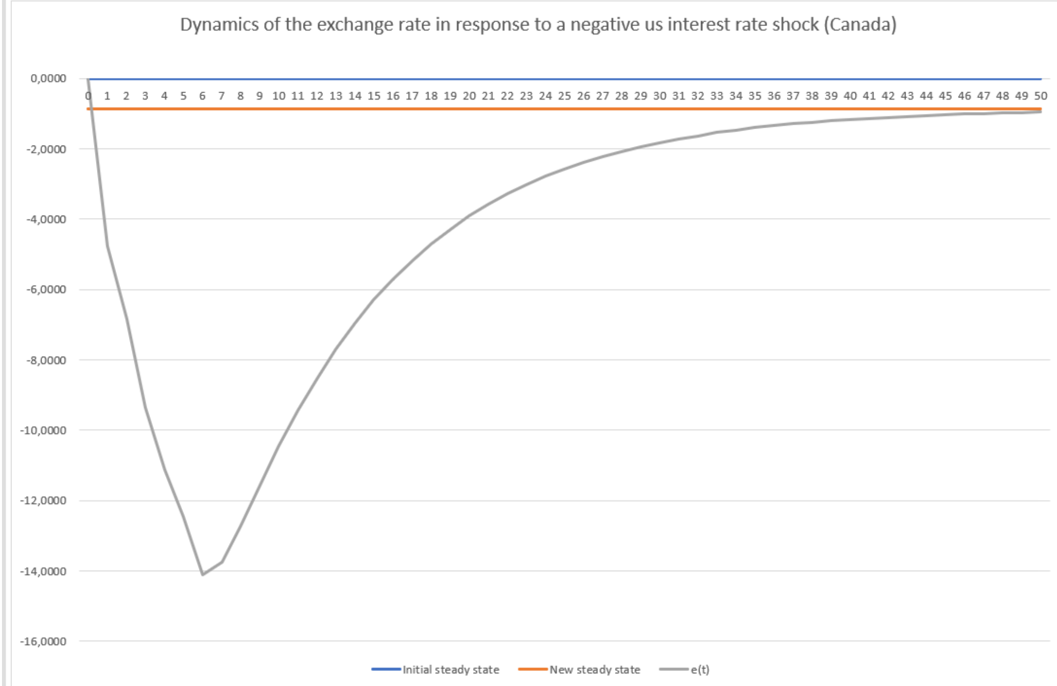
5.4.2 Negative U.S. interest rate

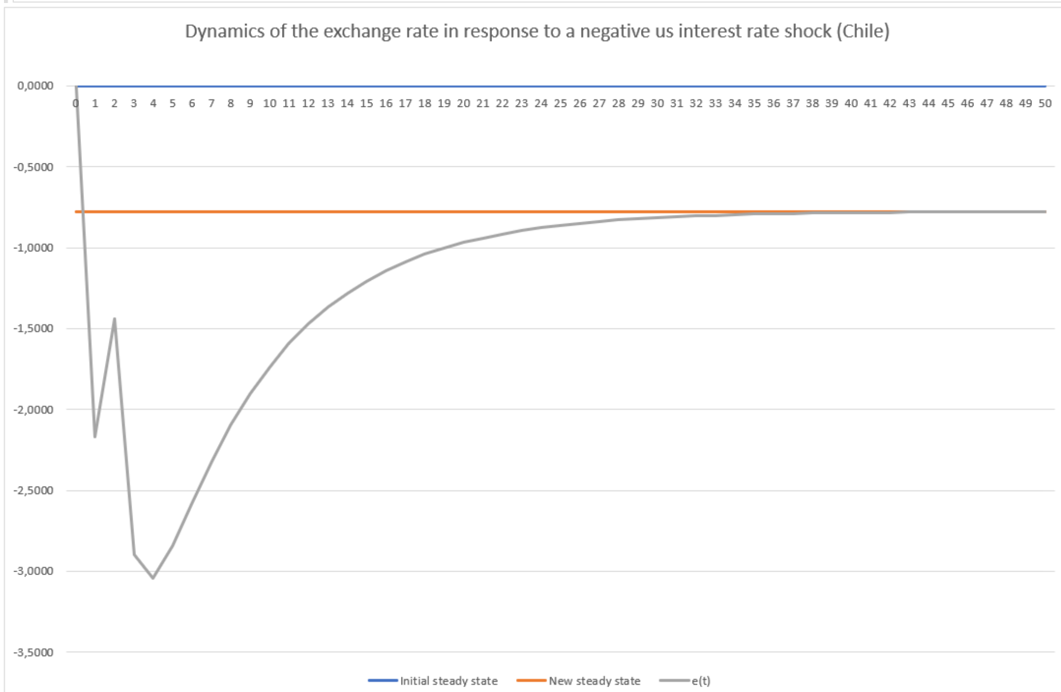
After a negative U.S. interest rate shock making the interest rate differential increases by 1 percentage point, the impulse response of the exchange rate for Canada shows an appreciation in the short-term and in the long-term. Four interest rate coefficients out of five in the short-term are significant at $\alpha = 0.1$. The long-run interest rate coefficient is negative but non-significant. This estimated coefficient is -0.0085 meaning that a percentage point increase of the interest rate differential appreciates in the long-run the exchange rate by 0.85 percent. In the short-run, an appreciation of 14 percent is observed after 6 months.

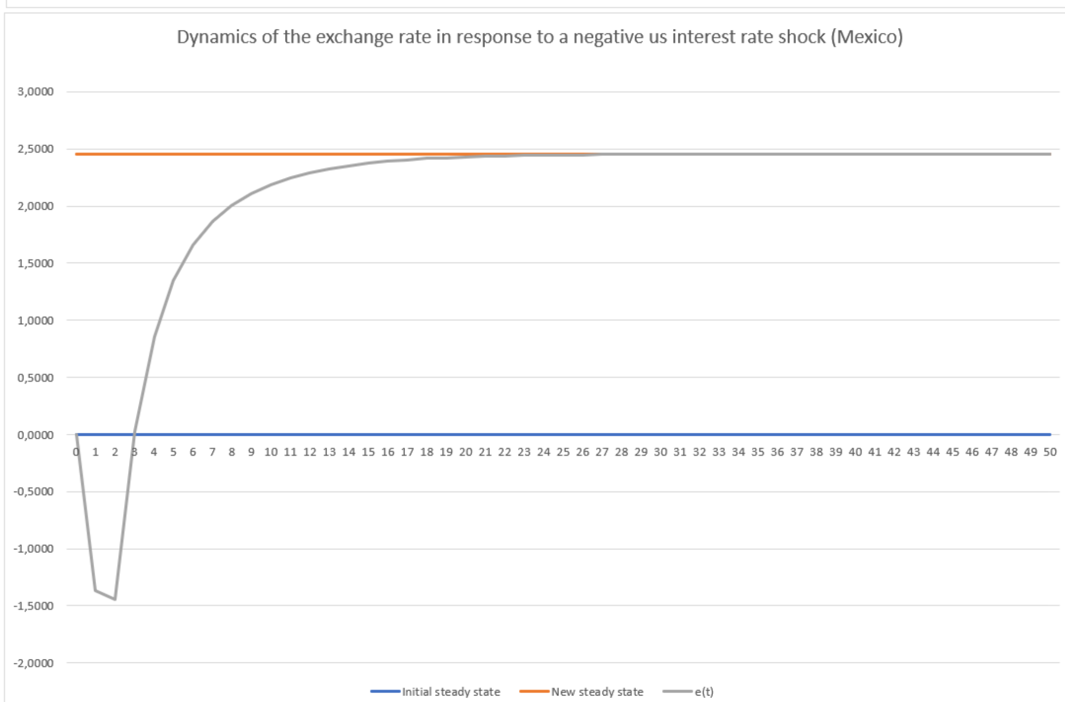
Chile have two significant interest rate coefficients out of three in the short-term but does not have a significant long-run coefficient. The impulse response shows an appreciation of the exchange rate following the exogenous shock. The long-run estimated coefficient shows an appreciation of the exchange rate by 0.7 percent. In the short-run, after 5 months, an appreciation of 3 percent is observed.

Mexico does not have a significant long-run interest rate coefficient. For the short-run coefficients, only one out of three coefficients are significant. The impulse response shows a short-term appreciation of 1.5 percent observed after 2 months and a long-term depreciation of 2.5 percent.

For Canada and Chile, the negative shock of the U.S interest rate generates in the short-term an appreciation stronger than its long-run appreciation. It means that these two countries have an overshooting of the exchange rate after the negative U.S. interest rate shock. Mexico is the only country which have a depreciation of the exchange rate in the long-run.


Dynamics of the exchange rate in response to a negative us interest rate shock (Canada)
Initial steady state
New steady state
e(t)

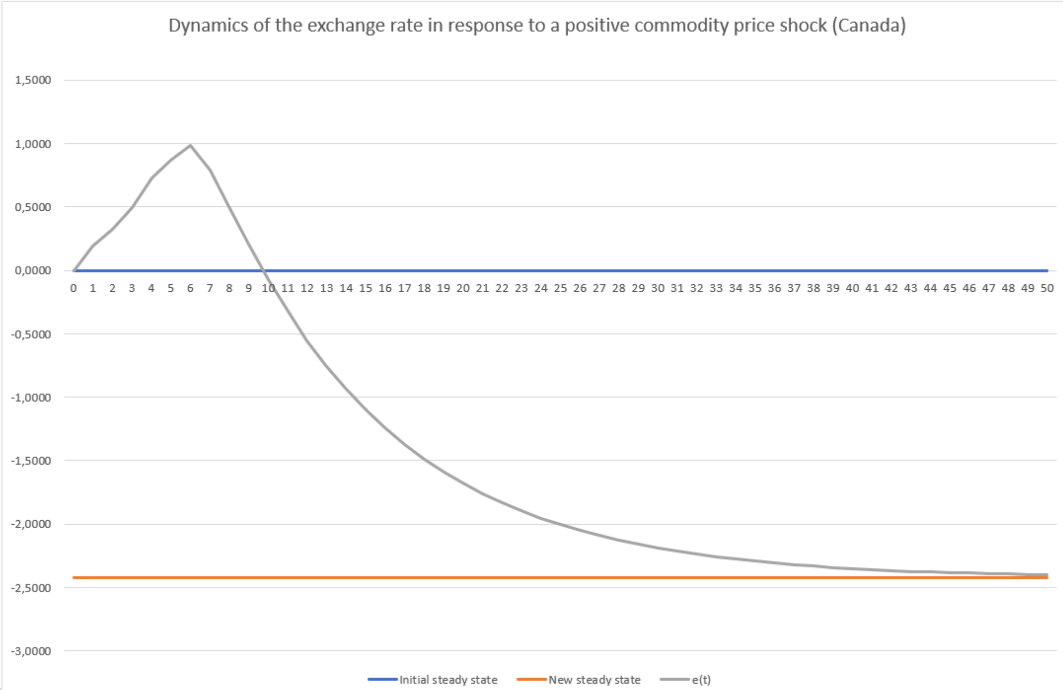

Dynamics of the exchange rate in response to a negative us interest rate shock (Chile)
Initial steady state
New steady state
e(t)

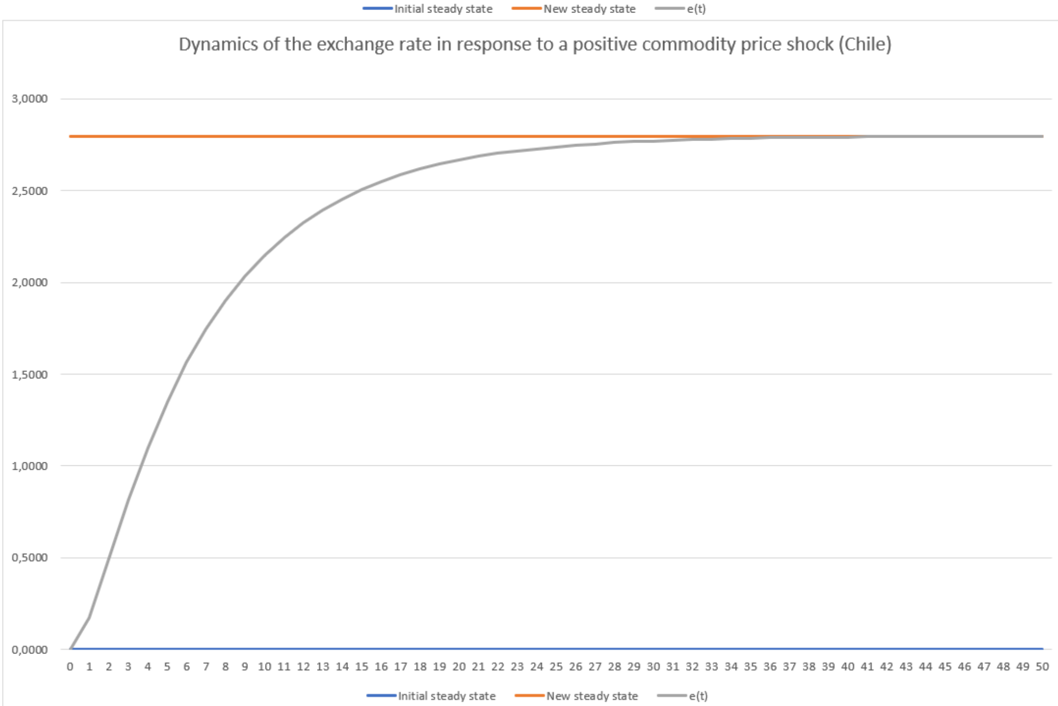

Dynamics of the exchange rate in response to a negative us interest rate shock (Mexico)
Initial steady state
New steady state
e(t)

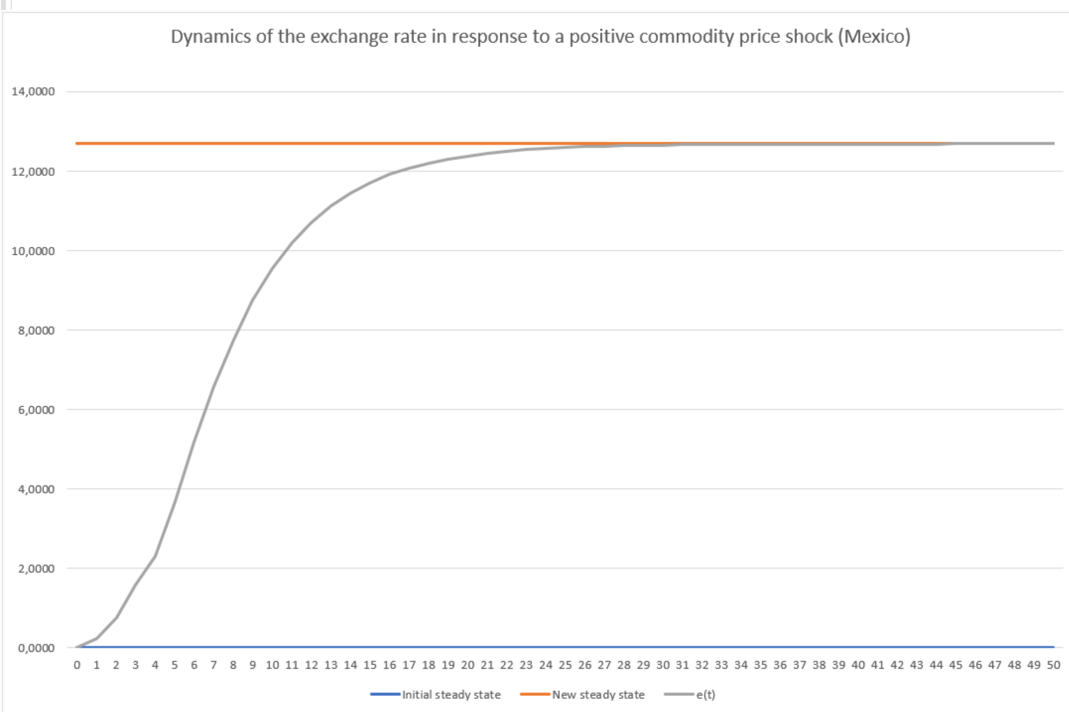
5.4.3 Positive commodity price shock

After a positive commodity price shock making the commodity price increases by 100 percent, the impulse response of the exchange rate for Canada shows a depreciation in the short-term and it appreciates in the long term. Two commodity price coefficients out of six in the short-term are significant at $\alpha = 0.1$. The long-run commodity price coefficient is not significant. This estimated long-run coefficient is -0.024 meaning that following a 100 percent increase in the commodity price, the exchange rate appreciates by 2.4 percent.

Chile does not have any significant commodity price coefficients and its impulse response shows a depreciation that takes place progressively to reach 2.8 percent following the increase in the commodity price. This pattern is the same as Mexico for which almost all the commodity price coefficients in the short-term are significant at $\alpha = 0.1$ as well as its long-term coefficient. Its long-term coefficient shows that following a 100 percent increase in the price of the commodity, the exchange rate depreciate by 12 percent. This result contradicts the theoretical expectation of an appreciation of the exchange rate after the commodity price shock.


Dynamics of the exchange rate in response to a positive commodity price shock (Canada)
1,5000
1,0000
0,5000
0,0000
-0,5000
-1,0000
-1,5000
-2,0000
-2,5000
-3,0000
Initial steady state
New steady state
e(t)


Dynamics of the exchange rate in response to a positive commodity price shock (Chile)
3,0000
2,5000
2,0000
1,5000
1,0000
0,5000
0,0000
Initial steady state
New steady state
e(t)


Dynamics of the exchange rate in response to a positive commodity price shock (Mexico)
14,0000
12,0000
10,0000
8,0000
6,0000
4,0000
2,0000
0,0000
Initial steady state
New steady state
e(t)

6 Local Projection

The Local projection (LP) methodology has first been developed by Jorda (2005). The purpose of local projection is to estimate impulse responses. These impulse responses should be similar to the one generated by a Vector autoregression (VAR). On one side, Barnichon and Brownlees (2017) argues that the impulse responses generated by local projection following an exogenous shock (out of the system) are less efficient than the impulse responses generated by a correctly specified VAR system.[13] Ramey and Zubairy (2018) emphases that the Local Projection method produces significant oscillation with long-run estimations. They also mention a trade-off between not imposing restrictions and efficiency. On the other side, Jorda (2005) and Barnichon and Brownless (2017) mention that Local Projection is more robust to misspecifications than a VAR. The result of the VAR depends on the specifications used to identify the impulse response after the shock. Iacovello and Navarro (2018) refers in their introduction to result of studies about the international effect of the U.S. monetary action made using a VAR. They mention that the assumption used to specify the VAR does not hold because of incoherence with the data. In such a case, the result of the impulse response is impacted as the VAR does not permit to approximate correctly the dynamical system by iterating forward.

In the previous section, the ARDL methodology was used. Many articles in the literature used this model because of the separation of the short-term and long-term useful to check if the short-term effect of an exogenous shock is more important than its long-term. The ARDL approach estimates a single equation giving a limited number of coefficient relative to each exogenous variable. But when we compare the ARDL and the LP, the LP provides more reliable impulse responses as the LP estimates the effect of the shock for each horizon, it is more easy to approximate the data generating process, namely the dynamic of the exchange rate in response to each exogenous shock, than with a single ARDL equation.

By using the Local Projection approach, we will compute the response of the exchange rate to a positive money supply, a negative U.S. interest rate or a positive commodity price shock without assuming any (possibly wrong) structural specification to identify the impulse response. We will be able to know if there is an overshooting of the exchange rate by looking at the dynamic given by the impulse response.

[13]One can consider the LP as the consistent impulse response and the specified VAR as the efficient case and test how consistent is the VAR one. If the VAR is correctly specified, it should be close to the LP with a more efficient impulse response.

6.1 Model

The model used in the Local Projection section is following :

$$y_{t+h} = \alpha_h + \beta_h shock_t + \phi_h x_{t-1} + \Sigma_{j=1}^{k} e_{t-j} + u_{t+h} \tag{7}$$

It estimates by OLS the impact of the exogenous shock, namely β_h, on the endogenous variable y_{t+h}. This process is made for each horizon h. We will obtain as much equations as we have horizons. The impulse response will graph each β with respect to its horizon.

The endogenous variable y_{t+h} is the exchange rate and the $shock_t$ whether the monetary, the U.S. interest rate or the commodity price shock. The other variables of the equation 4 will be considered as control variables x. These control variables are lagged by one period. Some lag of the endogenous variable will be included in the equation. u_{t+h} is the error term.

6.2 Result

6.2.1 Positive Monetary shock

In this part, we have generated by local projection the impulse response of the exchange due to an exogenous monetary shock for the 3 countries of analysis. In that case the equation will be

$$e_{t+h} = \alpha_h + \beta_h M_t + \phi_h x_{t-1} + \Sigma_{j=1}^{k} e_{t-j} + u_{t+h} \tag{8}$$

where e_{t+h} the exchange rate at different horizon, $shock_t$ the exogenous shock which is M_3 the relative money supply, x_{t-1} the vector of lagged control variables which contains the log difference GDP, nominal interest rate differential, the relative inflation rate and the log commodity price index. u_{t+h} is the error term. This equation contains lagged value of the exchange rate. For each value of h, k is determined by the AIC criterion.

With a confidence interval of $\alpha = 0.1$, Canada have in the first ten periods a depreciation. After that, the exchange rate appreciates over the time to attain after 30 months an appreciation of 2 percent.

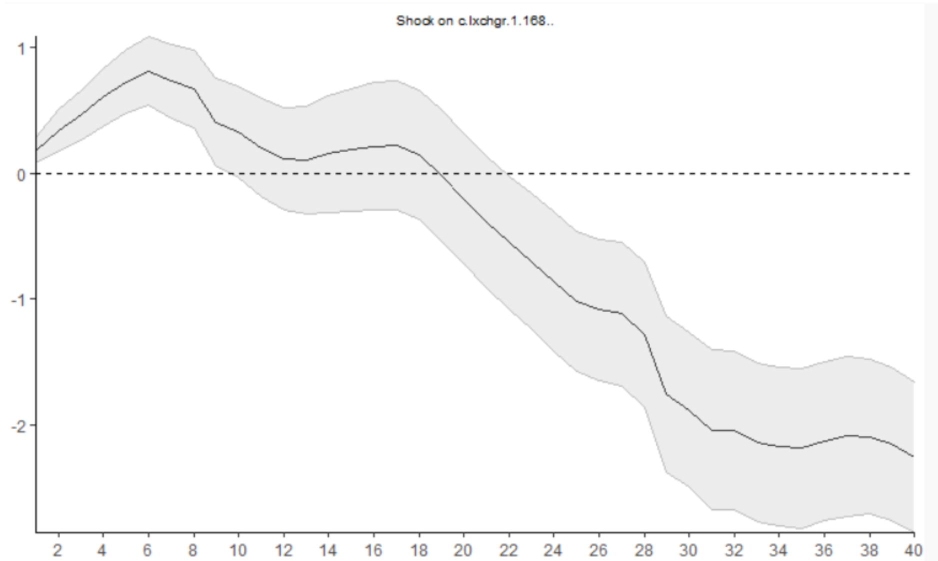
Following the monetary shock of 1 percent increase in the relative money supply, the Chilean peso is depreciated with respect to the U.S. dollar. The impulse response increases progressively and this depreciation is higher than 1 percent after 14 months and goes below 1 at around 0.75 to remain stable.

The Mexican peso also have a progressive increases of the impulse response after the monetary shock. This increase however is guided toward the long-term equilibrium of 1 percent depreciation that is approximately reached after 25 months.

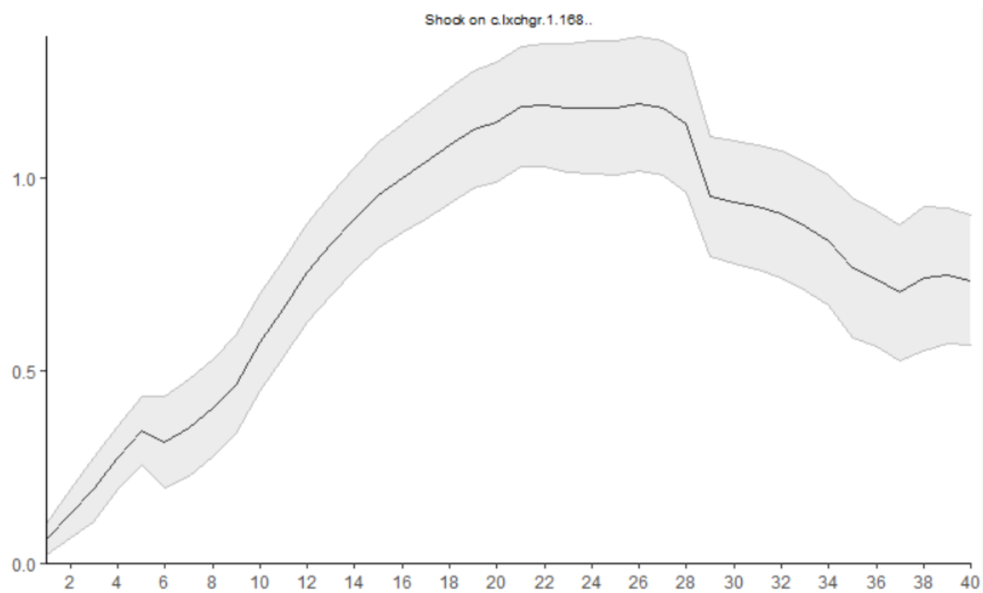
Chile have a clear overshooting of the exchange rate where on the other side Mexico have an depreciation without any overshooting phenomena. The Canadian dollar appreciates in the long-run even after a depreciation in the short-run.

Dynamics of the exchange rate in response to a positive monetary shock

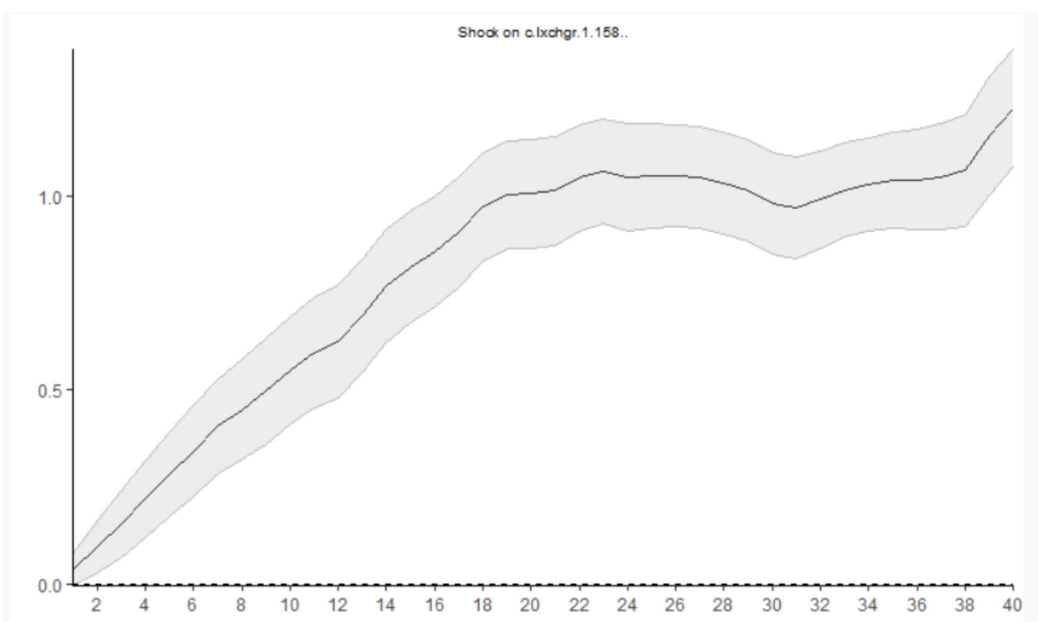
Canada



Chile



Mexico



6.2.2 Negative U.S. interest rate shock

In this part, we have generated by local projection the impulse response of the exchange due to a negative U.S. interest rate shock for the 3 countries of analysis. In that case the equation will be

$$e_{t+h} = \alpha_h + \beta_h r_t + \phi_h x_{t-1} + \Sigma_{j=1}^{k} e_{t-j} + u_{t+h} \tag{9}$$

with $shock_t$ the exogenous shock which is r_t the interest rate differential and compare to the previous section the money supply is now a control variable.

After having a negative U.S. interest rate shock that makes the interest rate differential increases by 1 percentage point, we expect to have an appreciation. But the Canadian dollar does depreciate. This level of depreciation is at most 20 percent after the shock.

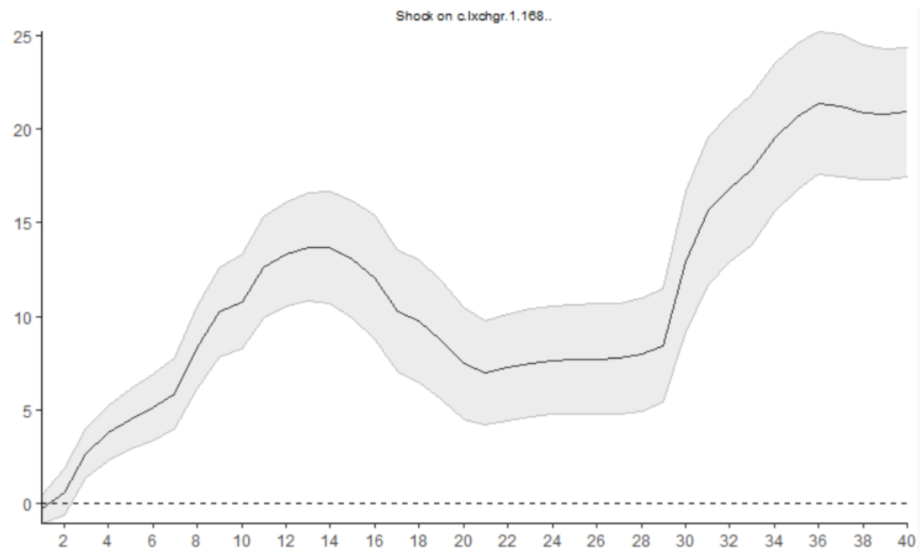
The Chilean peso appreciates, and reaches 3 percent appreciation after 18 months. The impulse response shows that after 30 months the effect of this appreciation have disappeared. After 38 months, the exchange rate depreciates for by 4 percent.

The graph relative to the Mexican peso shows that first, there is a depreciation of around 1 percent following the shock of one percentage point of the interest rate differential. After around 20 months, the exchange rate appreciates to reach after 30 months 5 percent.

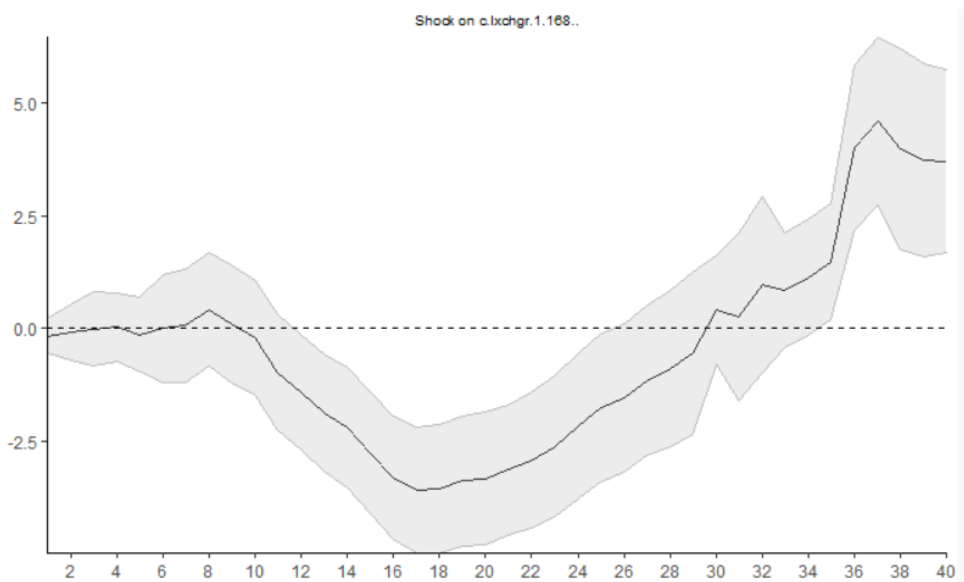
Following the negative U.S interest rate shock, the result does not respect the overshooting according to which in short-run, we should have a higher appreciation than in the long-run.

Dynamics of the exchange rate in response to a negative us interest rate shock

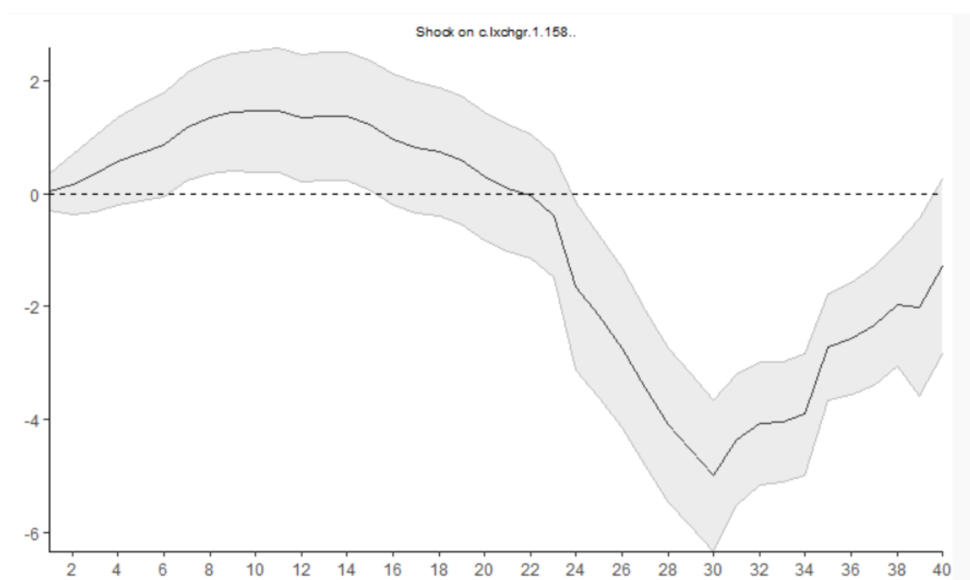
Canada



Chile



Mexico



6.2.3 Positive commodity price shock

In this part, we have generated by local projection the impulse response of the exchange due to an exogenous commodity price shock for the 3 countries of analysis. In that case the equation will be

$$e_{t+h} = \alpha_h + \beta_h cp_t + \phi_h x_{t-1} + \Sigma_{j=1}^{k} e_{t-j} + u_{t+h} \tag{10}$$

with $shock_t$ the exogenous shock which is cp_t the log commodity price index and compare to the previous section the interest rate differential is now a control variable.

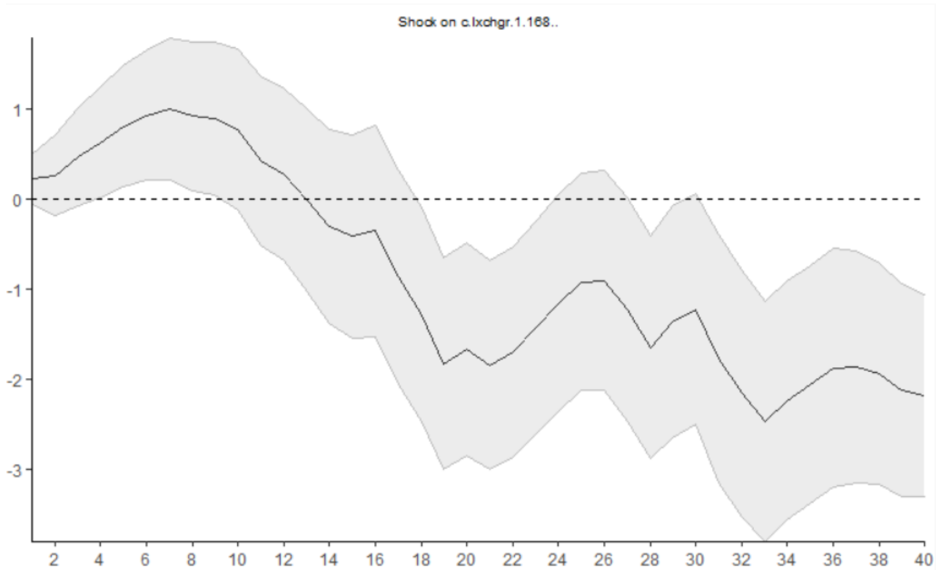
Following an increase of the commodity price, We expect to have an appreciation of the exchange rate. After this positive shock of 100 percent on the commodity price, for Canada, the tendency of the significant part is in favor of an appreciation of the exchange rate after 18 months. This appreciation is significant at $\alpha = 0.1$ in the long-run and is around 2 percent. However, we can observe a depreciation of 1 percent from the 4th to the 10th month following the shock.

For Chile, the impulse response is non-significant during the 40 months analysed. Mexico have a significant depreciation during the 40 months that follows the commodity price shock. The exchange rates depreciates approximately by 1.5 percent.

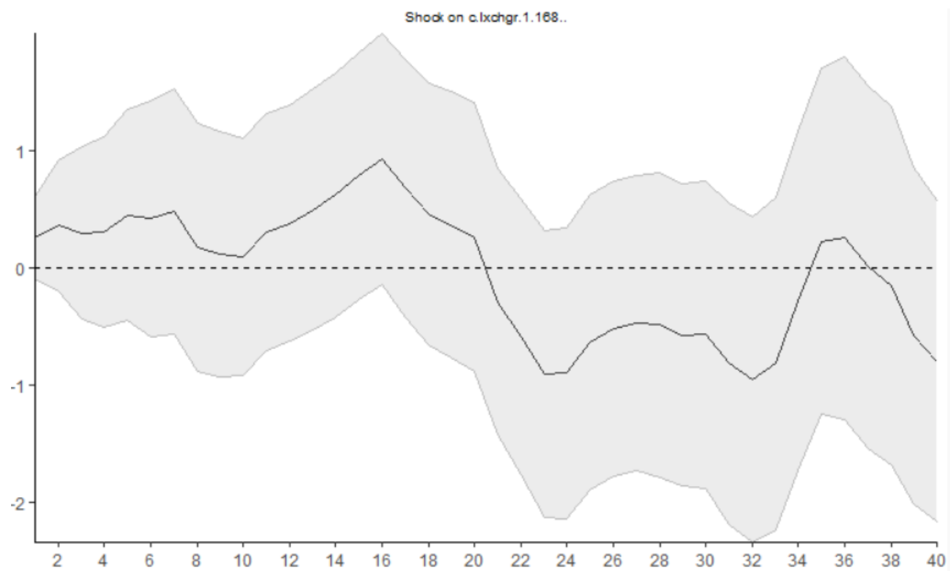
Following the result of this section, we cannot argue that after a commodity price shock there is an overshooting of the exchange rate. We do not observe an appreciation in short-term higher than a long-term appreciation.

Dynamics of the exchange rate in response to a positive commodity price shock

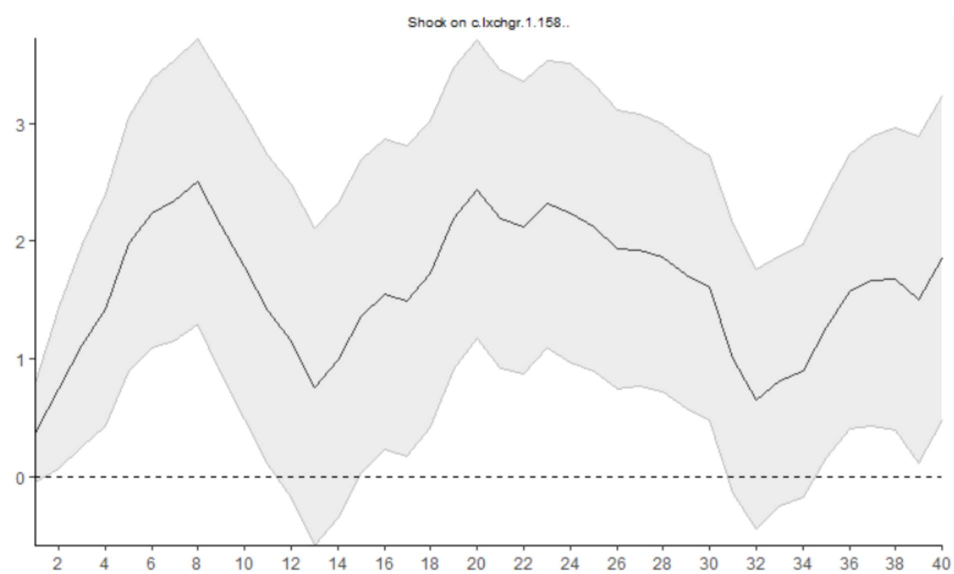
Canada



Chile



Mexico



7 Similarities and differences between ARDL and LP results

After presentation of the result in the two previous sections, this section wants to emphasis the important similarities and differences in the result obtained between the ARDL model and the LP model.

If we compare after a monetary shock the result from the ARDL and LP for Canada, the first periods indicate in the two cases a depreciation. However, the appreciation that occurs after the depreciation is stronger in the case of the LP, bringing the effect of the monetary shock on the exchange rate to become an appreciation. In the case of Chile, the LP and the ARDL gives evidence for an overshooting of the exchange rate after the monetary shock. The effect of an increase of 1 percent of the relative monetary supply with the LP occurs nonetheless more progressively and is less, around 0.75 percent in the long-run and 1 percent in the short-run, than the ARDL, around 1 percent in the long-run and 2.5 percent in the short-run. The Mexican peso depreciates in long-term in the LP and ARDL for around 1 percent and 0.7 percent respectively after the increase of the relative money supply. However in the short-term, the LP only shows a progressive depreciation toward the long-run equilibrium when the ARDL model indicates an appreciation of the exchange rate.

Concerning the increase of the interest rate differential by 1 percentage point due to the negative U.S interest rate shock, for Canada, the result of the LP and ARDL are different. The first indicates a depreciation after the shock when the second shows an appreciation with an overshooting. In the ARDL, the Chilean peso appreciates and an overshooting occurs. In the LP, we have a depreciation that begins after 10 months followed by an appreciation more important than the initial depreciation. For Mexico, the ARDL indicates an appreciation followed by a depreciation when the LP shows first a depreciation and then an appreciation.

Following the increase of 100 percent of the commodity price, for Canada, in the two models shows similar results in the short-run where we have an depreciation of 1 percent and in the long-run with an appreciation of approximately 2 percent. The LP result of Chile is not significant at $\alpha = 0.1$ where the ARDL shows an appreciation of 2.8 percent. The two impulse responses of the Mexican peso show a depreciation of the currency after the shock of 1.5 percent for the LP and 12 percent for the ARDL.

8 Robustness check

8.1 ARDL: Hausman test

In this section, we will conduct a Hausman test on the long-run coefficient for money supply for Canada and Chile. These two countries have a significant long-run coefficient for money supply. The idea is to see what is the behaviour of this coefficient when the commodity price index is added in the model. The Hausman test is performed on the money supply coefficient of the long-run relationship for which the commodity price of these two countries is not significiant [14]. This has a negative impact on the Bound F-test that is more significant without the variable relative to the commodity price. That said, the additional variable in these two cases makes the long-run coefficient of money supply more significant. To check if the long-run variable of money supply is also consistent with the non-significant commodity price index in the relationship, a Hausman test is conducted. The relationship without the variable relative to the commodity price is assumed to be consistent and the efficient case is the one with the commodity price index (coherent with the standard errors). The Hausman test is chi-square with one degree of freedom with as a null hypothesis that the money supply coefficient is, in addition to be efficient, consistent in the long-run relationship with the commodity price index. The alternative hypothesis tells that the money supply coefficient is only consistent in the long-run relationship without the commodity price index.

At $\alpha = 0.1$, for Canada and Chile, we do not reject the null hypothesis. As the chi-square critical value at 10 percent is 2.71, their respective result, 0.682 and 0.0119, is not higher than this value. The conclusion is that adding the commodity price index makes the long-run coefficient for money supply more efficient and that it is then better to use the relationship with the commodity price index than the one without.

Table 6: Hausman test on the coefficient of money supply for Canada and Chile

	Canada		Chile	
	Efficient	Consistent	Efficient	Consistent
m	**2.47**	**3.16**	**1**	**0.99**
s.e	*0.7*	*1.09*	*0.2*	*0.22*
F-test value	*3.96*	*4.78*	*4.22*	*4.73*
Hausman test chi(1)=2.71 at $\alpha = 0.1$	*0.682*		*0.0119*	

[14] See table 5

8.2 LP: change in the commodity price index

This robustness check will consist of a change of index for the commodity price index. As mentioned before, to construct the index, the each commodity price is weighted according the share of the net export of the commodity in the output. In this section, the price to form the index used will be weighted not according to the net export but to the share of the export of the commodity in the output.

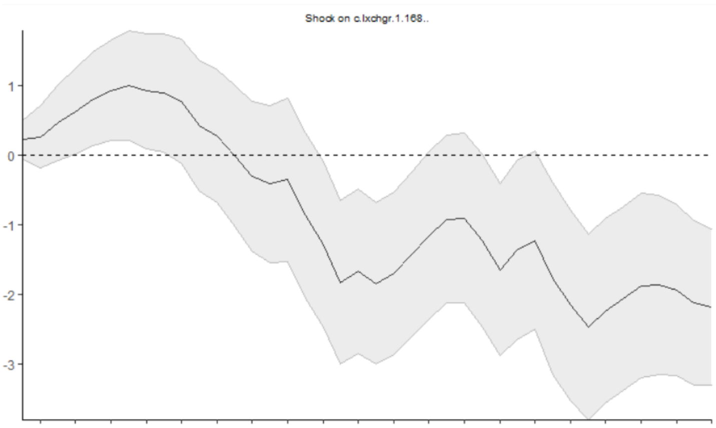
After a positive shock of 100 percent on the commodity price, we see that the two version of the commodity price index gives almost the same impulse response. The level of appreciation for Canada is around 2 percent when on the other side Mexico still have an depreciation of around 1.5 percent. The impulse response of Chile shows with the export weighted index a non-significant appreciation at $\alpha = 0.1$ during the entire period.

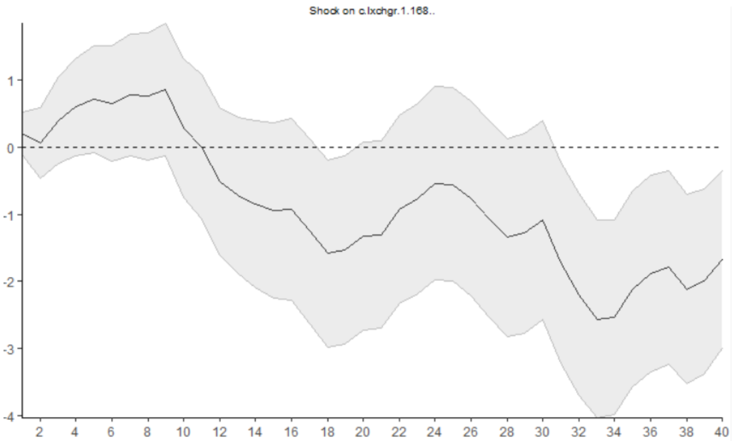
Robustness check : Dynamics of the exchange rate in response to a positive commodity price shock

Net export

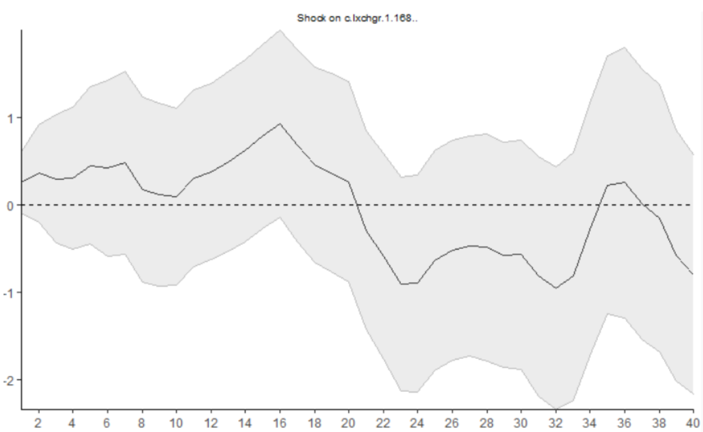
Export

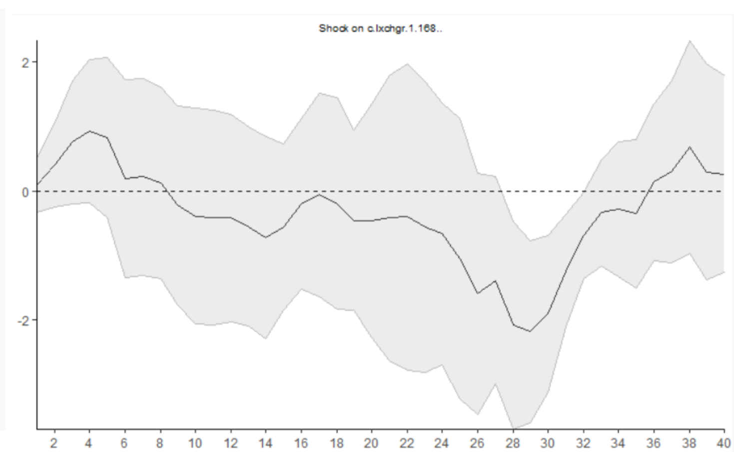
Canada



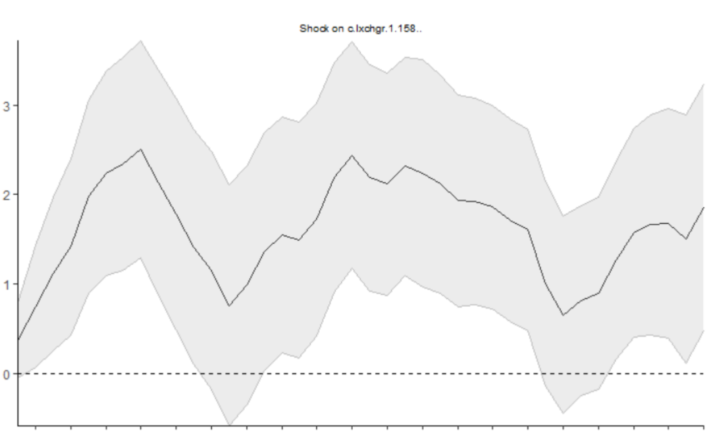


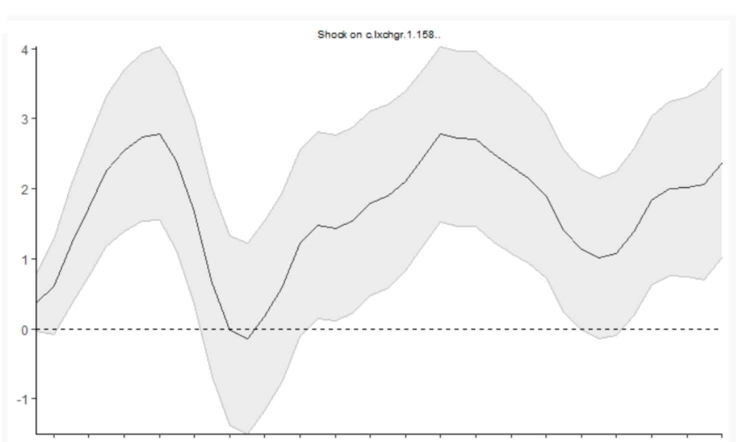
Chile





Mexico





9 Conclusion

In the first sections, we have argued that the exchange rate can be in addition to the classical relationship that hold by the quantity theory of money, the Unconvered Interest rate Parity and the Purshasing Parity Power influenced by the primary commodity prices for the three countries of analysis, Canada, Chile and Mexico. A modified regression equation for the exchange rate has been first developed in order to be used in the ARDL and LP sections.

The first econometric approach, the ARDL, is also widely used in previous studies for his short and long-run separation with the use of cointegration. For Canada and Chile, there were no doubt about the existence of a long-run relationship as the F-test statistics were above the upper bound at 10 percent of significance, where on the other side, some doubts persist for Mexico. The impulse responses of the ARDL shows some case of overshooting specially for after the shock of the money supply and of the interest rate for Canada and Chile.

The second econometric approach used, the LP, confirms on one side some result from the ARDL model, as the overshooting of Chile after the monetary shock, but on the other side have different results, as the depreciation of the Canadian dollar after the negative U.S interest rate shock. It was specially hard to distinguish some similar impulse response pattern after the negative interest rate shock.

Adding the commodity price index makes a more efficient regression. By checking the long-run coefficient of the relative money supply for Canada and Chile, there is some evidences that the commodity price index in the model is useful to obtain a more efficient estimation regardless of the decrease of the statistic of the Bound F-test. This phenomenon happens as the commodity price is not significant in these long-run relationship.

The reaction of the exchange rate to the commodity price shock is almost the same in the ARDL and the LP for Canada and Mexico. These result does not meet an overshooting where the exchange rate would appreciate in the short-term more than its long-run appreciation. On one side for Canada, there is depreciation in the short-run and an appreciation in the long-run, on the other side for Mexico, we have a depreciation of the exchange rate. The robustness check that changes the index in the LP approach confirms the patterns of these impulse responses.

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Table 7: Appendix table: ARDL equation for Canada with t-statistics

Canada ARDL(2,1,6,1,6,6)

Variable	Lags					
	0	1	2	3	4	5
d.e		**0,322*** **				
		4,38				
d.y	**-0,1894**					
	-1,242					
d.m	**0,9606*** **	**-0,2384**	**-0,431* **	**-0,1535**	**0,371**	**0,886*** **
	3,787	*-0,934*	*-1,738*	*-0,616*	*1,515*	*3,72*
d.π	**0,00757* **					
	1,77					
d.r	**-0,0475*** **	**-0,00814**	**-0,02273*** **	**-0,015* **	**-0,0146* **	**-0,02054*** **
	-5,767	*-1,00*	*-2,863*	*-1,904*	*-1,845*	*-2,6*
d.cp	**0,0019**	**0,0025**	**0,0032**	**0,0037* **	**0,0028**	**0,00301** **
	1,29	*0,92*	*1,365*	*1,77*	*1,52*	*1,99*
Intercept	**0,0177**					
	1,126					
e		**-0,06931*** **				
		-3,00				
y		**0,0424**				
		0,534				
m		**0,171*** **				
		2,86				
π		**0,00001**				
		0,005				
r		**-0,0005**				
		-0,14				
cp		**0,00168**				
		-0,507				

Root Mean Square Error : 0.01390

R-squared: 0.5351 / Adjusted R-squared: 0.4415

F-statistic: 5.713 on 27 and 134 DF, p-value: 3.153e-12

*Significant at 10 percent, **Significant at 5 percent, *** Significant at 1 percent

d.variable is the first difference variable

Table 8: Appendix table: ARDL equation for Chile with t-statistics

Chile ARDL(2,5,8,7,3,1)

Variable	Lags							
	0	1	2	3	4	5	6	7
d.e		**0,25*** **						
		2,99						
d.y	**0,087**	**0,36*** **	**0,336*** **	**0,296*** **	**0,24*** **			
	1,06	*2,99*	*2,72*	*2,7*	*2,99*			
d.m	**1,33*** **	**0,3**	**-0,138**	**0,53**	**-0,28**	**-0,03**	**1,32*** **	**-0,85** **
	3,44	*0,71*	*-0,317*	*1,23*	*-0,66*	*-0,07*	*3,27*	*-2,35*
d.π	**0,01*** **	**-0,006* **	**-0,0035**	**-0,001**	**-0,0064* **	**0,0012**	**-0,016*** **	
	4,29	*-1,81*	*-1,06*	*-0,4*	*-1,88*	*0,36*	*-4,6*	
d.r	**-0,021*** **	**0,011**	**-0,017*** **					
	-3,35	*1,63*	*-3*					
d.cp	**0,0017**							
	0,9							
Intercept	**0,65*** **							
	3,11							
e		**-0,104*** **						
		-3,212						
y		**-0,1828** **						
		-2,51						
m		**0,104*** **						
		4,085						
π		**0,003** **						
		2,186						
r		**-0,0008**						
		-0,377						
cp		**0,0029**						
		1,337						

Root Mean Square Error : 0.01784

R-squared: 0.5415 / Adjusted R-squared: 0.4305

F-statistic: 4.877 on 31 and 128 DF, p-value: 8.405e-11

*Significant at 10 percent, **Significant at 5 percent, *** Significant at 1 percent

d.variable is the first difference variable

Table 9: Appendix table: ARDL equation for Mexico with t-statistics

Mexico ARDL(2,3,4,5,3,4)

Variable	Lags				
	0	1	2	3	4
d.e		**0.389*** **			
		4.4			
d.y	**0.195**	**0.357**	**-0.23**		
	0.678	*1.283*	*-0.818*		
d.m	**-0.178**	**-0.227**	**-0.338**	**-0.453**	
	-0.518	*-0.622*	*-0.913*	*-1.296*	
d.π	**0.011** **	**-0.013*** **	**0.014*** **	**-0.0038**	**0.004**
	2.5	*-2.756*	*2.817*	*-0.84*	*0.996*
d.r	**-0.013***	**0.0005**	**0.01**		
	-1.648	*0.061*	*1.371*		
d.cp	**0.002**	**-0.008** **	**-0.006***	**-0.007*** **	
	0.822	*-2.185*	*-1.834*	*-2.817*	
Intercept	**0.23*** **				
	3.57				
e		**-0.1*** **			
		-3.51			
y		**0.09**			
		1.17			
m		**0.07*** **			
		2.61			
π		**-0.003**			
		-1.58			
r		**0.003**			
		1.1			
cp		**0.013*** **			
		2.82			

Root Mean Square Error : 0.02225

R-squared: 0.3399 / Adjusted R-squared: 0.2024

F-statistic: 2.483 on 26 and 126 DF, p-value: 0.00044

*Significant at 10 percent, **Significant at 5 percent, *** Significant at 1 percent

d.variable is the first difference variable