3-19-2019

Essays on International Macroeconomics and Monetary Policy

Renzo M. Alvarez Oyola
ralva021@fiu.edu

Follow this and additional works at: <https://digitalcommons.fiu.edu/etd>

Part of the [International Economics Commons](#), and the [Macroeconomics Commons](#)

Recommended Citation

Alvarez Oyola, Renzo M., "Essays on International Macroeconomics and Monetary Policy" (2019). *FIU Electronic Theses and Dissertations*. 4049.
<https://digitalcommons.fiu.edu/etd/4049>

This work is brought to you for free and open access by the University Graduate School at FIU Digital Commons. It has been accepted for inclusion in FIU Electronic Theses and Dissertations by an authorized administrator of FIU Digital Commons. For more information, please contact dcc@fiu.edu.

FLORIDA INTERNATIONAL UNIVERSITY

Miami, Florida

ESSAYS ON INTERNATIONAL MACROECONOMICS
AND MONETARY POLICY

A dissertation submitted in partial fulfillment of the

requirements for the degree of

DOCTOR OF PHILOSOPHY

in

ECONOMICS

by

Renzo Manuel Alvarez Oyola

2019

To: Dean John F. Stack, Jr.

Steven J. Green School of International and Public Affairs

This dissertation, written by Renzo Manuel Alvarez Oyola, and entitled Essays on International Macroeconomics and Monetary Policy, having been approved in respect to style and intellectual content, is referred to you for judgment.

We have read this dissertation and recommend that it be approved.

Cem Karayalcin

Mihaela Pinte

Laura De Carli

Hakan Yilmazkuday, Major Professor

Date of Defense: March 19, 2019

The dissertation of Renzo Manuel Alvarez Oyola is approved.

Dean John F. Stack, Jr.

Steven J. Green School of International and Public Affairs

Andrés G. Gil

Vice President for Research and Economic Development
and Dean of the University Graduate School

Florida International University, 2019

© Copyright 2019 by Renzo Manuel Alvarez Oyola
All rights reserved.

DEDICATION

To my parents, Fanny and Manuel. Without their unconditional support, understanding, and most of all love, I would not be where I am today.

ACKNOWLEDGMENTS

I wish to thank the members of my committee for their invaluable support throughout my studies. Dr. Mihaela Pinteau was always there for academic and professional advice. Dr. Cem Karayalcin's availability and good humor certainly made everything easier. And Dr. De Carli always made me feel I could reach out to her for guidance. I would also like to thank my major professor, Dr. Hakan Yilmazkuday, for always pushing me to do my best and for guiding me all these years. I also gratefully acknowledge the financial support of a Florida International University Dissertation Year Fellowship, and of the National Science Foundation and the AEA Mentoring Program for travel support to present part of this work. A special thank you goes to Dr. Marie Mora for facilitating numerous events and opportunities through my time in the Mentoring Program, and to my mentor Dr. Susan Pozo, for her invaluable advice. Finally, I would like to acknowledge my fiancée, Celeste, for being a constant source of support and strength, and for her loving understanding throughout countless working weekends and holidays.

ABSTRACT OF THE DISSERTATION
ESSAYS ON INTERNATIONAL MACROECONOMICS
AND MONETARY POLICY

by

Renzo Manuel Alvarez Oyola

Florida International University, 2019

Miami, Florida

Professor Hakan Yilmazkuday, Major Professor

A sound monetary policy depends on a solid understanding of how external shocks reverberate throughout the economy. This is particularly true in emerging market economies under the inflation targeting (IT) framework since these economies tend to be subject to large external shocks, and don't have a long IT track record. My dissertation studies the macroeconomic consequences of external shocks under IT in emerging market economies, and the policy response to such shocks.

The first chapter studies whether foreign exchange interventions (FXI) are effective under IT in the context of commodity prices shocks. It also explores the extent to which lack of public confidence in the central bank's ability to meet its inflation objectives may frustrate the success of FXI. Using an interacted panel vector autoregression framework, I find that, when the central bank fights simultaneous appreciation and inflationary pressures driven by positive commodity price shocks, FXI indeed leads to less exchange rate appreciation. However, lack of credibility — reflected by the (de-)anchoring of inflation expectations — can undermine a central bank's FXI effort since less credible central banks increase interest rates more aggressively to stabilize inflation. The simultaneous effort to depreciate the currency is thus weakened in the presence of higher rates.

The second chapter investigates the implications of international trade costs shocks for exchange rate determination under different inflation targets. Using a dynamic stochastic general equilibrium model I show that, given a shock to international trade costs, the nominal exchange rate exhibits higher volatility under higher inflation targets. The results suggest that monetary policy authorities should choose inflation targets with caution, especially in a context of uncertainty regarding international trade costs.

The third chapter empirically estimates the extent to which changes in the exchange rate induce changes in the prices of imported agricultural goods in Turkey. I show that agricultural commodities have a low and incomplete exchange rate pass-through. The results suggest that Turkish monetary policymakers may allow nominal exchange rate fluctuations to stabilize real activity without having to worry about a spike in CPI inflation induced by higher import prices.

TABLE OF CONTENTS

CHAPTER	PAGE
INTRODUCTION	1
1. FOREIGN EXCHANGE INTERVENTION, INFLATION TARGETING, AND CENTRAL BANK CREDIBILITY	7
1.1 Introduction	7
1.2 Methodological Approach	15
1.3 Results	39
1.4 Conclusion	53
2. EXCHANGE RATE DETERMINATION UNDER ALTERNATIVE INFLA- TION TARGETS: THE ROLE OF TRADE COSTS	69
2.1 Introduction	69
2.2 Model	74
2.3 The mechanism of a trade costs shock	98
2.4 Simulations	100
2.5 Conclusion	107
3. EXCHANGE RATE PASS-THROUGH INTO MICRO PRICES	117
3.1 Introduction	117
3.2 Data	121
3.3 Empirical Methodology	122
3.4 Results	125
3.5 Conclusion	129
APPENDICES	159
VITA	195

LIST OF TABLES

TABLE	PAGE
1.1 FXI and Business Cycle Variables	56
3.1 ERPT with Alternatives Exchange Rate Lags	134
3.2 Alternative Controls	135
3.3 ERPT in Different Years	136
3.4 ERPT: Threshold on Exchange Rate Changes, All Price Changes.	137
3.5 ERPT with Threshold on Exchange Rate Changes, Nonzero Price Changes.	138
3.6 ERPT with Threshold on Frequency of Price Changes, All Price Changes.	139
3.7 ERPT with Threshold on Frequency of Price Changes, Nonzero Price Changes.	140
3.8 ERPT with Threshold on Storage Potential, All Prices	141
3.9 ERPT with Threshold on Storage Potential, Nonzero Prices	142
3.10 ERPT and Thresholds - Summary Table	143
A.1 Countries and Summary Statistics	178
A.2 Variable Definitions and Data Sources	179
B.1 Endogenous Variables	186
B.2 Exogenous Variables	186
B.3 Parameterization	194

LIST OF FIGURES

FIGURE		PAGE
1.1	Exchange Rates and Exchange Rate Management, post IT adoption. . .	57
1.2	Inflation Expectations, and Inflation gaps, selected countries.	58
1.3	Commodity Price Indexes.	59
1.4	Exchange Rate Dynamics and Foreign Exchange Intervention.	60
1.5	Exchange Rate Dynamics and Expectations-based CBC.	61
1.6	FXI and Expectations-based CBC	62
1.7	Exchange Rate Dynamics: FXI and Expectations-based CBC.	63
1.8	Exchange Rate Dynamics: FXI and Expectations-based CBC	64
1.9	Exchange Rate Dynamics and Foreign Exchange Intervention, EM13. . .	65
1.10	Exchange Rate Dynamics and Observed-inflation-based CBC, EM7. . .	66
1.11	Exchange Rate Dynamics and Observed-inflation-based CBC, EM13. . .	67
1.12	FXI and Central Bank Credibility, EM13	68
2.1	NKPC Coefficients vs Annualized Trend Inflation	110
2.2	Impulse Response Functions: Trade Costs Shock in the Home Economy	111
2.3	Impulse Response Functions: Nominal Exchange Rate	112
2.4	Quarterly Changes of the Nominal Exchange Rate	113
2.5	Impulse Response Functions: Trade Costs Shock to both Home and Foreign	114
2.6	Impulse Response Functions: Real Exchange Rate	115
2.7	Quarterly Changes of the Real Exchange Rate	116
3.1	Exchange Rate over Time: Turkish Lira per U.S. Dollar	144
3.2	Fixed Effects: Exchanges Rates Changes vs Ramadan	144
3.3	Fixed Effects: Exchanges Rates Changes vs Weekdays	145
3.4	Fixed Effects: Exchanges Rates Changes vs Months	145
3.5	Fixed Effects: Exchanges Rates Changes vs Years	146

3.6	Fixed Effects: Price Changes vs Ramadan	146
3.7	Fixed Effects: Price Changes vs Weekdays	147
3.8	Fixed Effects: Price Changes vs Months	147
3.9	Fixed Effects: Price Changes vs Years	148
3.10	Threshold Analysis: Exchange Rate Change	148
3.11	Threshold Analysis: Frequency of Price Change	149
3.12	Threshold Analysis: Storage Potential	149
A.1	Inflation Targets, Expected Inflation, and Observed Inflation.	159
A.2	Inflation Expectations Gap and Observed Inflation Gap.	160
A.3	Credibility Index: $CRED^{LLR}$	161
A.4	Commodity Prices Indexes: Country-specific and Broader Indexes	162
A.5	Commodity Prices and the Exchange Rate.	163
A.6	Foreign Exchange Intervention: $FXI_{i,t}^{RA}$	164
A.7	Foreign Exchange Intervention: $FXI_{i,t}^{LYS}$	165
A.8	Central Bank Credibility: $CRED_{i,t}^{EGap}$	166
A.9	Central Bank Credibility: $CRED_{i,t}^{LLR}$	167
A.10	FXI and Central Bank Credibility: $FXI_{i,t}^{RA}$ and $CRED_{i,t}^{LLR}$	168
A.11	FXI and Central Bank Credibility: $FXI_{i,t}^{LYS}$ and $CRED_{i,t}^{EGap}$	169
A.12	FXI and Central Bank Credibility: $FXI_{i,t}^{LYS}$ and $CRED_{i,t}^{LLR}$	170
A.13	Central Bank Credibility: $CRED_{i,t}^{YoY}$	171
A.14	Central Bank Credibility: $CRED_{i,t}^{1Q}$	172
A.15	Central Bank Credibility: $CRED_{i,t}^{YoY}$, Extended Sample	173
A.16	Central Bank Credibility: $CRED_{i,t}^{1Q}$, Extended Sample	174
A.17	FXI and Central Bank Credibility: $FXI_{i,t}^{RA}$ and $CRED_{i,t}^{YoY}$	175

A.18	FXI and Central Bank Credibility: $FXI_{i,t}^{RA}$ and $CRED_{i,t}^{1Q}$	176
A.19	FXI and Central Bank Credibility: $FXI_{i,t}^{LYS}$ and $CRED_{i,t}^{1Q}$	177
B.1	Impulse Response Functions: Trade Costs Shock in the Home Economy, Home Response	192
B.2	Impulse Response Functions: Trade Costs Shock in the Home Economy, Foreign Response	193

INTRODUCTION

The sound formulation and implementation of monetary policy rests on an appropriate understanding of how external shocks reverberate throughout the economy. This is particularly the case in emerging market economies under the inflation targeting monetary policy framework. Under inflation targeting the Central Bank announces a target for the inflation rate and conducts policy in order to achieve it. This implies that other policy objectives — like exchange rate stability — come second to the primary objective of price stability. This in turn means that central banks constantly face policy trade offs when external shocks occur, and policymakers need to fully understand the consequences of these shocks before devising the policy response.

These considerations are especially true in emerging market economies for various reasons. First, these economies tend to be subject to large external shocks. Second, policymakers in these countries don't have a long track record under inflation targeting. Third, even though the exchange rate is supposed to float freely under inflation targeting, the fact remains that most emerging markets pay close attention to exchange rate developments for reasons that range from financial stability to external competitiveness. With this in mind, understanding the interactions between the economic shocks and both inflation and the exchange rate, and between the shock and the monetary policy response is crucial. With this in mind, my dissertation studies the macroeconomic consequences of external shocks under inflation targeting in emerging market economies and the monetary policy response to such shocks.

In the first chapter, I begin by noting that in recent years, significant exchange rate pressures, driven by large external shocks, have induced inflation targeting central banks in emerging market economies to intervene in foreign exchange markets, while trying to stabilize inflation. The viability of foreign exchange interventions

under inflation targeting has generated an intense debate given their theoretical incompatibility. This chapter analyzes whether foreign exchange interventions are effective under inflation targeting, and the extent to which lack of public confidence in the central bank's ability to meet its inflation objectives may frustrate the success of foreign exchange interventions.

Using an interacted panel vector autoregression framework and a set of seven inflation targeting emerging markets, I find that, when the central bank fights simultaneous appreciation and inflationary pressures driven by positive commodity price shocks, foreign exchange intervention indeed leads to less exchange rate appreciation. However, lack of credibility — reflected by the (de-)anchoring of inflation expectations — can undermine a central bank's foreign exchange intervention effort. The reason is that less credible central banks need to increase interest rates more aggressively to stabilize inflation. This undermines the simultaneous effort to depreciate the currency by inducing a new source of appreciation pressure on the exchange rate.

The results suggest that the appreciation effect of the interest rate response to a loss of credibility reflected by a 1 percentage point increase in the inflation expectations gap can cancel out the depreciation effect of a purchase of foreign currency equivalent to 0.75 percent of GDP. This is a large effect, considering that, on average, countries in the sample hold international reserves in the amount of 10 percent of GDP.

This paper contributes not only to the literature on foreign exchange intervention and the literature on central bank credibility mentioned above, but also to a recent debate on how inflation targeting emerging markets should conduct monetary policy when they are hit by large external shocks. Over time, the literature has noticed that inflation targeting central banks in emerging market economies (EMEs) have

generally succeeded at keeping inflation in check (see [IMF, 2018a](#)). However, the desirability to meet other policy objectives, especially after the Global Crisis, has prompted a debate on how the framework should be complemented. In this debate, there is no consensus on the merits and viability of exchange rate management within the inflation targeting framework. However, in recent years, the literature has found evidence that there may be room for some degree of exchange rate management within inflation targeting, especially in emerging markets.

Within this reality, the findings of this chapter suggest that foreign exchange intervention in inflation targeting EMEs may indeed serve as a buffer to contain appreciation pressures in the context of large external shocks. However, they also suggest that policymakers should proceed with caution. In general, it's clear that central banks should avoid engaging in foreign exchange interventions that are inconsistent with the monetary policy stance — such as trying to curb appreciation pressures while raising interest rates. But the results of this paper emphasize that this should be particularly the case in situations in which inflation expectations are not well-anchored and policy credibility is lacking. To the extent that the public does not view the central bank as being credible, policymakers could find that they need to conduct more aggressive foreign exchange interventions in order to overcome their own more aggressive monetary policy stance. For policymakers, the results presented in that chapter offer a further incentive to increase the quality of the inflation targeting framework by increasing transparency and devising better communication strategies with the aim of increasing the credibility of monetary policy. The economic benefits of well-anchored inflation expectations and high credibility are well documented in the literature. This first chapter offers another reason to strive for further improvements in policy credibility.

In the second chapter, I investigate the implications of shocks to international trade costs (e.g. transportation costs) for exchange rate determination under the inflation targeting regime. Understanding these shocks is important since they affect the prices of imported goods, which in turn can affect inflation. These shocks can trigger monetary policy responses by inducing inflation deviations from the target. Further, these consequences may vary with the magnitude of the inflation rate targeted by the central bank. Indeed, there is heterogeneity regarding what inflation rate is targeted in different countries, and in fact, some countries may even be considering raising their targets. For instance, since the crisis, some economists have argued that Central Banks could raise their inflation targets (say, from 2% to 4% in the case of the Federal Reserve) so that monetary policy can have more room for action in the context of deflationary shocks (see [Blanchard et al. \(2010\)](#) and [Ball \(2013\)](#)). Controlling for the prevailing inflation target is important since, as [Ascari and Sbordone \(2014\)](#) have shown in a closed economy model, higher inflation targets are associated with a more volatile and unstable economy, and they can induce a more aggressive monetary policy response to inflation deviations from target. However, the interaction between trade costs shocks and IT has not been taken into account in the literature and a number of questions remain unanswered.

To fill this gap in the literature, I develop a two-country dynamic stochastic general equilibrium model (DSGE) of the New Keynesian type. I then simulate this micro-founded New-Keynesian model to test its implications. When the monetary policy authority uses a CPI-based Taylor Rule, I find that a trade costs shock received by the Home economy leads to a permanent depreciation of the nominal exchange rate, and this permanent depreciation is more pronounced under higher inflation targets. Further, I find that the nominal exchange rate exhibits changes of larger magnitude in each period following the shock under higher inflation targets,

suggesting a higher volatility. Lastly, I find that this type of shock induces the real exchange rate to exhibit a slow pace of adjustment towards its equilibrium value. The implied persistence of the real exchange rate is higher under trade costs shocks than under monetary policy shocks.

In short, under this calibration exercise, the model predicts that given a shock to international trade costs, the nominal exchange rate exhibits higher volatility under higher inflation targets. The results suggest that monetary policy authorities should choose inflation targets with caution, especially in a context of uncertainty regarding international trade costs.

In the last chapter, chapter I empirically estimate the extent to which changes in the exchange rate induce changes in the prices of imported agricultural goods — the exchange rate pass-through (ERPT) — in Turkey. Since increases in import prices can increase consumer price inflation the measure obtained is of great importance to policymakers. To do this, I introduce a novel good-level data set of daily wholesale prices of imported agricultural products into Turkey.

The data set has two main advantages over others used in the literature. First, it consists of daily prices. To my knowledge, this is one of a few databases available in which the frequency of the observations is daily. One of the most important contributions of this chapter is to establish a relationship between the level of exchange rate pass-through (ERPT) and the storage potential of an agricultural product (a concept related to the literature on the economic effects of depreciation of inventories). Since some agricultural commodities have a storage potential of only a few days, having a daily investigation is crucial for establishing this relationship. Second, the data source contains the corresponding daily prices for domestically produced agricultural products. This allows me to construct a relevant measure that controls for all other macroeconomic developments in Turkey which may affect the prices of

agricultural commodities, thereby allowing me to properly identify the pure effect of nominal exchange rate changes on prices.

In general, the chapter presents evidence that agricultural commodities have a low and incomplete exchange rate pass-through (ERPT) measure. The results of standard empirical analysis are in line with the findings in the literature. In particular, this chapter provides evidence for *incomplete* daily ERPT of about 5%. The key contribution of the chapter arises once nonlinearities are taken into account. Using a threshold regression model, the chapter provides evidence of an ERPT measure that doubles to about 10% when daily nominal exchange rate changes exceed 0.55%, when the prices of the imported commodities change more than 3.12% of the time, and when the storage potential of a product is above 10 weeks. This last results is in line with an economic channel in which the seller of a perishable commodity wishes to sell the good as soon as possible, due to its high depreciation rate. This implies that sellers of products with lower storage potential will be less inclined to try to pass-through their higher costs to consumers in the event of an exchange rate shock. On the contrary, importers of commodities with longer shelf lives may pass-through their higher costs simply because they can afford to wait for an optimal price. This channel is in line with the studies of Kryvtsov and Midrigan (2012), and Alessandria et al. (2013), who show that the optimal price of a seller decreases as the depreciation rate of its inventories increase.

The results suggest that Turkish monetary policymakers may allow nominal exchange rate fluctuations to stabilize real activity in the face of external shocks without having to worry about a spike in CPI inflation induced by higher prices of imported agricultural commodities.

CHAPTER 1

FOREIGN EXCHANGE INTERVENTION, INFLATION TARGETING, AND CENTRAL BANK CREDIBILITY

1.1 Introduction

In recent years, emerging markets have faced significant exchange rate pressures driven by large terms-of-trade movements and sizable international capital flows.¹ These pressures have posed serious challenges for the central banks in these countries, particularly for those with formal inflation targeting (IT) frameworks. The reason is that IT requires exchange rate flexibility (Mishkin, 2000; Mishkin and Savastano, 2001), yet excessive exchange rate volatility can induce well-known adverse effects in emerging markets (Nordstrom et al., 2009).² This yields the familiar “fear of floating” (Calvo and Reinhart, 2002) or, more recently, the “fear of appreciation” (Levy-Yeyati et al., 2013) typically associated with these economies. Consequently, IT central banks tend to respond to exchange rate pressures driven by large external shocks by intervening in foreign exchange markets, while using interest rate policy to stabilize inflation. Managing the exchange rate under IT, however, is a hotly debated topic in the literature. Not only is there no consensus on whether there is room for foreign exchange interventions within the IT framework, it is also not clear what determines the effectiveness of these interventions under this regime.

In this paper, I show that IT central banks in emerging market economies (EMEs) are indeed able to curb exchange pressures by intervening in foreign ex-

¹The terms-of-trade movements in emerging markets have been largely driven by sharp commodity price fluctuations, while the large international capital flows are largely the result of monetary policy normalization in advanced economies.

²This is due to the critical role the exchange rate plays in these economies

change markets, but that the effectiveness of these interventions may depend on whether the public has confidence in the central bank’s ability to meet its inflation objectives. This effect takes place specially in situations in which the central bank fights simultaneous appreciation and inflationary pressures driven by external shocks. Certainly, the literature has demonstrated that the effective formulation and transmission of monetary policy can be determined by whether the public’s inflation expectations are anchored to the central bank’s target (Ha et al., 2018). This paper shows that the credibility of the central bank — reflected by the degree of anchoring of inflation expectations — can also determine the success of foreign exchange interventions. In particular, I quantify the extent to which lack of credibility can undermine a central bank’s foreign exchange intervention effort when it fights simultaneous appreciation and inflationary pressures driven by commodity price shocks.

Any attempt at identifying the determinants of foreign exchange intervention (FXI) effectiveness, however, must first address the methodological challenge posed by the endogenous nature of the FXI choice. Indeed, interventions attempt to push against market pressures: central banks accumulate (sell) international reserves to curb appreciations (depreciations). That is, the decision to intervene in foreign exchange markets is driven by contemporaneous exchange rate movements, which makes the decision endogenous. As Adler et al. (2015) point out, unaddressed, the endogeneity bias tends to conceal the effectiveness of FXI.

To overcome the endogeneity challenge, I use the Interacted Panel Vector Autoregression (IPVAR) framework introduced in Towbin and Weber (2013). In this setup, the dynamics of the endogenous variables can vary with country characteristics; here the FXI intensity and degree of central bank credibility (CBC). Inducing an external shock that triggers appreciation and inflationary pressures, the model

exploits the exogenous nature of the shock and the cross-sectional variation of FXI and CBC. This allows me to observe the dynamics of the exchange rate for varying combinations of FXI intensities and degrees of CBC. The external shock used in this paper is a commodity export price shock. This is meant to reflect the fact that, as mentioned above, in recent years EMEs have faced significant exchange rate pressures (Figure 1.1a) driven by sharp commodity price movements and sizable capital flows. The literature, however, has mostly focused on the FXI response to international capital flows, devoting little attention to FXI in the context of commodity price shocks. One of the contributions of this paper is to fill this void.

With this empirical strategy I first analyze the independent effects of FXI and CBC on the exchange rate, and then their joint effects. Accordingly, I find the following: First, following a commodity export price shock, IT central banks in emerging markets conducting FXI are indeed able to curb appreciation pressures on the exchange rate. In particular, the exchange rate appreciates less (between 0.4 to 1.2 percentage points less) when the central bank intervenes heavily in foreign exchange markets than when it intervenes lightly. Equivalently, a purchase of foreign currency in the amount equivalent to 0.75 percent of GDP induces a 1 percent depreciation of the domestic currency. This result is highly significant, statistically and economically. In general, this result is consistent with the findings in Aizenman et al. (2012), who use an error correction approach to find that the accumulation of reserves in Latin America helps buffer the direct effect of transitory commodity terms-of-trade shocks on the real effective exchange rate. More broadly, the findings in this paper are consistent with the findings in Adler and Tovar (2011), Adler et al. (2015), Blanchard et al. (2015), and Daude et al. (2016), among others, who find empirical evidence for the effectiveness of FXI.

Second, following the external shock, relatively lower CBC is found to exacerbate the appreciation pressure on the exchange rate. The accompanying dynamics of inflation and of the policy rate response paint a picture of the underlying mechanism. In particular, the appreciation pressure on the exchange rate is intensified by the policy rate response given the shock’s simultaneous inflationary pressure. Following the shock, inflation increases more in economies with less credible central banks than in economies with more credible central banks. Accordingly, central banks with lower degrees of credibility raise policy rates more aggressively, which provides a further source of appreciation pressure on the exchange rate. The results suggest that a loss of credibility in the form of a 1 percent increase in the inflation expectations gap, ultimately leads to a 1.13 percent appreciation of the exchange rate.

This agrees with the underlying mechanism identified in theoretical models. For instance, [Neuenkirch and Tillmann \(2014\)](#) present a model in which agents’ inflation expectations are sensitive to deviations from the inflation target. To regain credibility, monetary policy under discretion sets higher interest rates today if average inflation exceeded the target in the past. That is, the model predicts that lower credibility forces the central bank to increase interest rates more aggressively. This prediction is confirmed in this paper. The result also confirms the empirical findings in [IMF \(2018b\)](#) who, in the context of general terms-of-trade shocks, find that the interest rate response to inflation deviations from target is more aggressive when inflation expectations are not well-anchored.³

Third, the estimation of the joint effects of FXI and CBC show that less credible central banks that engage in FXI to fight an appreciation see their intervention

³The analysis in [IMF \(2018b\)](#), however, stops short of discussing the implications for the exchange rate, and does not touch on foreign exchange interventions.

efforts undermined by the need to have a more aggressive policy rate response to fight the inflationary pressures of the underlying shock. In particular, the results suggest that the appreciation effect (through higher interest rates) of a loss of credibility reflected by a 1 percentage point increase in the inflation expectations gap can cancel out the depreciation effect of a purchase of foreign currency equivalent to 0.75 percent of GDP. Equivalently, an IT EME central bank needs to accumulate international reserves in the amount of 0.75 percent of GDP to overcome the appreciation pressure to which a 1 percent increase in the inflation expectations gap ultimately leads. This is a large effect, considering that, on average, countries in the sample hold international reserves in the amount of 10 percent of GDP, and that engaging in FXI and holding reserves is costly.⁴

As suggested above, the importance of credibility arises since FXI does not occur in isolation, but in a response to shocks that have consequences not only for the exchange rate, but also for inflation and output. When an external shock puts appreciation pressures on the exchange rate, the degree of credibility of an IT central bank may hinder the effectiveness of FXI through its effect on the aggressiveness with which policy interest rates need to be increased to fight simultaneous inflationary pressures.⁵

The potential for lack of coherence between exchange rate policy and inflation objectives in IT central banks is always there when the external shock places appreciation pressures on the exchange rate while simultaneously inducing inflationary pressures. For instance, Kamil (2008) provides evidence that in trying to slow

⁴For a discussion of the costs of foreign exchange interventions see Adler and Mano (2018)

⁵This channel is different from what the literature usually refers to as the *signaling channel* — the idea that interventions can be viewed by agents as a signal about the future stance of monetary and exchange rate policy (Sarno and Taylor, 2001)

down appreciation pressures in 2007, the Central Bank of Colombia’s large-scale intervention became incompatible with its inflation objectives. The results in this paper show that this potential tension between exchange rate and monetary policy is heightened with lower policy credibility. Beyond finding evidence that FXI in EMEs is effective, this paper suggests that not only policy coherence remains an important determinant of the effectiveness of FXI, but that central bank credibility plays a crucial role in determining the success of interventions. In this sense, this result is related to the finding in [Daude et al. \(2016\)](#), who look at the correlation between country-specific measures of intervention effectiveness and various macroeconomic indicators. They find that the effectiveness of intervention declines with inflation. The authors interpret this as evidence that lower credibility can reduce the effectiveness of FXI. That conclusion relies on an interpretation of realized inflation as a valid proxy for credibility. The results above, however, rely on credibility measures based on inflation expectations — the most commonly used measures of credibility in the literature (see [Demertzis et al., 2012](#)).

The final contribution of the paper is to show that observed inflation-based measures of credibility measures are informative and yield qualitatively similar results to those found using expectations-based measures. This result lends credence to the interpretation in [Daude et al. \(2016\)](#) discussed above. This may seem trivial given the high correlation between inflation expectations and realized inflation. However, credibility has a forward-looking interpretation, which implies that current inflation, or inflation from the recent past, *a priori* does not contain all the information found in the information set of agents forming expectations about the future. Indeed, the fact that the results are quantitatively more nuanced when using credibility measures based on observed inflation reflects this fact. Nevertheless, it’s important to know that measures of credibility based on observed inflation can be informative,

especially since data on inflation expectations is not publicly available for many emerging markets.

This paper contributes not only to the foreign exchange intervention and central bank credibility literatures mentioned above, but also to a recent debate on how IT emerging markets should conduct monetary policy in the face of large external shocks. Certainly, IT central banks in EMEs have generally succeeded at keeping inflation in check (see IMF, 2018a).⁶ However, the desirability to meet other policy objectives, especially after the Global Crisis, has prompted a debate on how the framework should be complemented.⁷ In this debate, there is no consensus on the merits and viability of exchange rate management within IT. In recent years, however, the literature has found evidence that there may be room for some degree of exchange rate management in IT EMEs.⁸ This seems reasonable given the crucial

⁶Some argue that this is due to EMEs graduating from pursuing procyclical policies (Vegh and Vuletin, 2014). Others say there are reasons to believe that low inflation in EMEs is the result of the “globalization of inflation” (see Ihrig et al., 2010). Nevertheless, Ha et al. (2018) show that domestic shocks rather than global shocks explain the lion’s share of the variation in domestic inflation. Similarly, Bems et al. (2018) find evidence that domestic rather than global factors have been the drivers of the improved inflation performance in EMEs since the mid-2000s, implying that policymakers can have significant influence over domestic inflation.

⁷See Baldwin and Reichlin (2013); Smets et al. (2014); Gillitzer et al. (2015); Debortoli et al. (2018); and Ghosh et al. (2016), among others.

⁸For instance, Ghosh et al. (2016) present a model in which judicious foreign exchange intervention can supplement inflation targeting especially in the face of volatile capital flows. They find that FXI is fully consistent with the central bank meeting its inflation target under IT, and that this is welfare enhancing insofar as the central bank cares about exchange rate volatility. Similarly, Airaudo (2016) presents a model in which management of the exchange rate greatly enhances the efficacy of inflation targeting. Further, studying inflation targeting Guatemala, Catalán-Herrera (2016) finds that intervention had a dampening effect on the daily exchange rate return’s volatility, although level effects are not found. Lastly, analyzing 37 countries, Berganza and Broto (2012) find that FXI in some IT countries has been more effective to lower exchange rate volatility than in non-IT countries.

role that the exchange rate plays in these economies.⁹ Normative questions aside, the reality is that sharp exchange rate fluctuations have triggered the response of IT EME central banks in recent years. Figure 1.1b plots a simple measure of exchange rate management for a group of IT and non-IT EMEs. The computed statistic ranges from 0 (representing a purely floating exchange rate) to 1 (representing a peg). The figure shows that many IT EMEs manage their exchange rates as actively as, and sometimes more actively than, non-IT EMEs.¹⁰¹¹ There is no reason to believe these central banks will stop conducting these interventions. This implies that it’s crucial to understand the determinants of FXI effectiveness and how policy credibility could facilitate or complicate the task of the policymaker.

Within this reality, the findings of this paper suggest that FXI in IT EMEs may indeed serve as a buffer to contain appreciation pressures in the context of large external shocks, but they suggest that policymakers should proceed with caution. In general, it’s clear that central banks should avoid engaging in foreign exchange interventions that are inconsistent with the monetary policy stance. But the results of this paper emphasize that this should be particularly the case in situations in which inflation expectations are not well-anchored and policy credibility is lacking. Insofar as the central bank is not credible, policymakers could find that they need to engage in more aggressive FXI to overcome their own more aggressive monetary

⁹From the pass-through of exchange rate changes to inflation, to currency mismatches, the exchange rate has a crucial role in EMEs. The importance is such that Aghion et al. (2009) even find that in less financially developed countries higher exchange rate volatility is associated with lower productivity growth.

¹⁰Adler et al. (2015) report a figure similar to Figure 1.1b for these and other countries over the 1996-2013. Ghosh et al. (2016) also use this statistic as a simple measure of FXI.

¹¹Not only does the empirical evidence show that IT central banks in EMEs conduct foreign exchange interventions (Ghosh et al., 2016), but surveys find that central banks acknowledge using interventions to curb excessive exchange rate volatility and calm disorderly markets (e.g. Neely, 2001 and Mihalkej, 2005). Curbing “disorderly conditions” in FX markets is in fact recommended by the IMF. See IMF (2017)

policy stance. For policymakers, the results presented here offer a further incentive to increase the quality of the IT framework by increasing transparency and devising better communication strategies with the aim of increasing the credibility of monetary policy. The benefits of well-anchored inflation expectations and high credibility are well documented in the literature. This paper offers another reason to strive for further improvements in policy credibility.

The rest of the paper is organized as follows: Section 3.3 defines and describes the measurement of the key variables for the empirical model, and describes the methodology; Section 3.4 presents the results; and Section 3.5 concludes.

1.2 Methodological Approach

As mentioned in the introduction, any attempt at studying the determinants of the effectiveness of foreign exchange interventions needs to overcome the endogenous nature of FXI.¹² In its attempt to overcome the endogeneity issue, the literature has resorted to the use of instrumental variables or the use of high frequency data. However, proper instruments are not readily available, and high-frequency estimates are not informative about the macroeconomic relevance (e.g. the persistent and cumulative effects) of FXI at horizons larger than a few days (Adler et al., 2015 and Blanchard et al., 2015). A further limitation is that high frequency data on a central bank’s foreign exchange position is often unavailable, which leads us to rely

¹²An example of the endogeneity of FXI is useful: Suppose that a given shock induces an 8 percent exchange rate appreciation in the absence of intervention. Suppose further that by conducting FXI the central bank is able to partially offset the appreciation pressure by 3 percent. The FXI would be deemed successful. However, simple correlations would pick up that a given amount of FXI was associated with a 5 percent appreciation of the exchange rate.

on proxies based on publicly available data like changes in international reserves (Adler and Tovar, 2011).

The approach to revealing the effectiveness of FXI in this paper is different from those previously used in the literature, and it rests on two observations. First, in combating the appreciation (depreciation) pressure of an external shock, an intervention — in the form of a purchase (sale) of foreign currency — need not fully overcome the appreciation (depreciation) to be deemed successful. The effective intervention need only show up in the form of an exchange rate that appreciated (depreciated) by a lower amount than it otherwise would have in the absence of intervention. Second, an empirical strategy that allows for observing the potential effect of FXI (described in the first point) and its determinants, needs to exploit the exogenous nature of an external shock that puts appreciation or depreciation pressures on the exchange rate, and then allow us to observe the exchange rate response under varying amounts of FXI and varying institutional characteristics.

With this in mind, to unveil the effects of FXI, I make use of the Interacted Panel Vector Autoregression (IPVAR) framework introduced in Towbin and Weber (2013). In this framework, the response of the endogenous variables to a given shock is allowed to vary with country characteristics. This strategy allows me to induce an external shock that triggers an exchange rate appreciation, and then observe the dynamics of the exchange rate at different intervention intensities. In particular, using a set of seven IT EMEs (and then thirteen in the robustness checks), I estimate an IPVAR model in which the coefficients are allowed to vary with the amount of FXI conducted by the central bank, and with the degree of CBC. Inducing a positive commodity exports price shock to the system, which tends to put inflationary and appreciation pressures on the economy, the framework exploits the exogenous nature of the shock and the cross-sectional variation of FXI intensities and degrees of CBC.

This allows me to analyze how the exchange rate response varies with the amount of FXI conducted and with the degree of CBC.

The plan for this section is as follows: Subsection 1.2.1 defines key variables and provides their measurement; Subsection 1.2.2 introduces the Interacted Panel Vector Autoregression framework; and Subsection 3.2 discusses the data used in this paper.

1.2.1 Definitions and Measurement

This subsection defines and provides a measure for three key variables used in the empirical model: central bank credibility, foreign exchange intervention, and commodity price shocks.

Measuring Central Bank Credibility

Central bank credibility is an institutional characteristic that, as [Blinder \(2000\)](#) points out, matters in theory, is believed to matter in practice, and is difficult to measure. Although it might be difficult to define, the overall intuition of what credibility means has not changed much over the years: credibility involves the ability of the central bank to meet its objectives.¹³ However, while the intuition may be clear, quantifying credibility is not straightforward, and will always involve using a proxy.¹⁴

¹³[Blinder \(2000\)](#) says that his favorite definition “involves matching deeds with words” and that “a central bank is credible if people believe it will do what it says”; while recently, James Bullard, president of the Federal Reserve Bank of St. Louis, linked the credibility of a central bank to its ability to meet its commitments ([Appelbaum, 2016](#)).

¹⁴This is, of course, the case of many other economic concepts: think of any concept that has the word “natural” in front of it, e.g. the natural rate of unemployment, or the natural interest rate. Measuring institutional characteristics is no less challenging.

In the context of IT, however, having an explicit objective — the inflation target — somewhat facilitates the proxy choice. Central banks in IT EMEs have generally succeeded in keeping runaway inflation in check since adopting IT. However, as seen in Figure 1.2a CPI inflation in these countries tends to, at the very least, linger near the inflation target bands.¹⁵ Missing the target or not provides a clear cut way of assessing whether a central bank is doing what it says it will do. Accordingly, the standard measure of credibility used in the literature has typically been a function of the inflation gap. In particular, the most commonly used measures are a function of either the difference between observed inflation and the central bank target (Bordo and Siklos, 2014; Bordo and Siklos, 2015; Ogrokhina and Rodriguez, 2018), or between inflation expectations and the central bank target (Bordo and Siklos, 2017; Levieuge et al., 2018). The first is a direct observation of whether or not the central bank actually meets its objectives, while the second is a measure of the anchoring of inflation expectations. In principle, a smaller inflation gap from the target implies a more credible policy.

I begin the investigation defining credibility measures based on the inflation expectations gap from the central bank target. In recent years, the literature has favored these expectations-based credibility measures given that credibility has a natural forward-looking interpretation — i.e. do market participants believe the central bank *will do* what it says? Accordingly, the main results of this paper use expectations-based credibility measures. However, publicly available data on inflation expectations is limited to seven IT EMEs. Therefore, after conducting the investigation with the expectations-based credibility measures — using the sample of seven countries for which the data is available — I go on to use credibility measures based on the observed inflation gap from the central bank’s target. Using

¹⁵Refer to Figure A.1 for a figure like 1.2a for all countries in EM13.

the latter I find results, for the thirteen EMEs in the sample, that are qualitatively equivalent to the findings using inflation expectations-based credibility measures. This should not be surprising given that past observed inflation is contained in the information set used to form expectations. For future reference, the sample of seven countries for which inflation expectations data is publicly available are Brazil, Chile, Colombia, Guatemala, Mexico, Peru, and Turkey. I will refer to this set of countries as EM7. The set of thirteen countries that will be used to conduct the analysis using CBC measures based on observed inflation include all those in EM7, plus Hungary, Indonesia, Philippines, Poland, Romania, and Thailand. I will refer to this set of countries as EM13.

Expectations-Based Credibility Measures

The first expectations-based measure is defined as the difference between the 1-year-ahead inflation expectation and the central bank inflation target. Defining the expectations-based gap in this manner reflects the fact that central banks set inflation targets over the medium term. Therefore, it is reasonable to assume that agents judge the central bank's ability to meet its commitment at annual instead of at business cycle frequencies.¹⁶ Formally, during quarter t , the first credibility measure is defined as

$$CRED_{i,t}^{EGap} = \pi_{i,t|t+4}^e - \bar{\pi}_{i,t} \quad \forall t, \quad (1.2.1)$$

where $\pi_{i,t|t+4}^e$ is the expected inflation for the year ahead, and $\bar{\pi}_{i,t}$ is the central bank's inflation target prevailing at time t . Although the objective $\bar{\pi}_{i,t}$ is time-

¹⁶Aside from the fact that targets are not meant to be met on a short-term, quarterly basis, using quarterly deviations from the implied quarterly target for the purposes of assessing policy credibility would contain noise in the form of temporary spikes in headline inflation. These temporary spikes don't necessarily affect the credibility of the central, especially if the spike is short lived and understood to be temporary. This can be, for instance, due to temporary spikes in the prices of imports.

varying in principle, except for a few gradual target reductions in the early years after adopting the IT regime, IT countries do not change the target often. Given that inflation targets are medium term objectives, I treat them as prevailing for the entire year for which they are announced. With this in mind, a consideration arises on what target to use in eq. (1.2.1) when the inflation target does change. Given that expectations are formed 1 year ahead, a target change implies that the year over which expectation are formed may include more than one inflation target. This implies that one must be careful with what inflation target should be used in eq. (1.2.1) to assess the anchoring of inflation expectations. Given that targets prevail for the entire calendar year — that is, a new target typically takes effect in January — then whether the expected inflation $\pi_{i,t|t+4}^e$ is formed with *information* that more than one target will bind during the horizon over which the expectation is formed is a function of the timing of the target change announcement. Insofar as the central bank announces changes in the target at the beginning of the year in which the new target will take effect no issues arise. However, if the central bank was to announce a new target for the following year several quarters before the new target takes effect agents would update their expectations, and the prevailing target would not be an up-to-date frame of reference to gauge credibility. Indeed, a more up-to-date frame of reference would involve a weighted average of the prevailing target and the target for the following year. I argue, however, that this is not a major concern given that some central banks in fact announce the target changes at the beginning of the year. For instance, Peru’s Central Bank announced its target change from 2.5 to 2 percent in January 2006, i.e. the beginning of the year in which the new target started binding (see [Central Reserve Bank of Peru, 2007](#)). More importantly, however, this is not a major concern given that during the sample period, central banks in the

countries studied maintained their inflation targets constant, on average, more than 93 percent of the time.

It should also be noted that the computation of $CRED_{i,t}^{EGap}$ involves taking the simple difference between inflation expectations and the inflation target, as opposed to the absolute or squared difference used in other studies (see [Bordo and Siklos, 2017](#)). Using the absolute difference tacitly implies that missing the target from below or from above has the same repercussions for a central bank’s credibility. A priori there is no reason to believe in symmetric effects, especially given the aversion for runaway inflation that characterizes IT regimes. In fact, countries don’t tend to miss the target symmetrically as one can observe in [Figure 1.2b](#) which plots the $CRED^{EGap}$ measure for a subset of EM7.¹⁷ Further, the empirical evidence provided in [Neuenkirch and Tillmann \(2014\)](#) and [Paloviita et al. \(2017\)](#) suggest that central banks react more aggressively — i.e. asymmetrically and non-linearly — when past inflation exceeded the target than when inflation fell below the central bank’s target. This suggests that policymakers consider positive deviations to be more serious than negative deviations from target.

The second expectations-based measure of central bank credibility is taken from [Levieuge et al. \(2018\)](#). In that study, the authors point out the shortcomings of existing credibility indexes. First, they note that existing indexes tend to rely on ad hoc threshold levels that imply a full loss of credibility. For instance, [Cecchetti and Krause \(2002\)](#) construct an index that takes the value of 1 — implying full credibility — if expected annual inflation is less than or equal to the inflation target. The index then decreases linearly as expected inflation increases, and takes a value of 0 — implying a total loss of credibility — when the expected inflation is greater than 20 percent. Second, [Levieuge et al. \(2018\)](#) argue that a credibility indicator

¹⁷Refer to [Figure A.2](#) for a figure like [1.2b](#) for all countries in EM13.

should be asymmetric in the sense that negative deviations of expected inflation from the target should be taken to be less serious than positive deviations from the target. This is in line with the discussion on asymmetric responses to inflation deviations from target above. With this in mind, [Levieuge et al. \(2018\)](#) suggest the following credibility measure:

$$CRED_{i,t}^{LLR} = \frac{1}{\exp(\tilde{\pi}_{i,t}^e) - \tilde{\pi}_{i,t}^e} \quad (1.2.2)$$

where $\tilde{\pi}_{i,t}^e$ is the deviation of expected inflation from the central bank's target. That is, using 1-year-ahead inflation expectations as above, $\tilde{\pi}_{i,t}^e = \pi_{i,t|t+4}^e - \bar{\pi}_{i,t}$. This indicator falls between 0 (implying total loss of credibility) and 1 (implying full credibility). The functional form of the denominator determines the profile of the indicator. In particular, for $\tilde{\pi}_{i,t}^e < 0$, the linear term in the denominator tends to dominate, which implies that the value of the index decreases, indicating a loss of credibility. However, for $\tilde{\pi}_{i,t}^e > 0$, the exponential term tends to dominate making the denominator increase exponentially with $\tilde{\pi}_{i,t}^e$. This implies that the index declines relatively rapidly with positive deviations from target than with negative deviations from target. Figure [1.2c](#) plots the measure $CRED^{LLR}$ for a subset of EM7.¹⁸ For instance, the measure captures well the fact that inflation in Chile tends to stay very close to the target, and therefore its profile paints the picture of a highly credible central bank.

It should be noted that [Levieuge et al. \(2018\)](#) suggest the index in eq. (1.2.2) particularly for the case when the central bank's target is a point target instead of a target range. They provide a similar index for the case when the central bank targets a range. In this case, the central bank attains full credibility as long as the expected inflation falls within the target range. A potential issue in using this

¹⁸Refer to Figure [A.3](#) for a figure like [1.2c](#) for all EM7 countries.

measure of credibility, however, is that there is no way to discern between a central bank that constantly hits the midpoint target or stays close to the midpoint target, and a central bank that constantly misses the midpoint of the target range and tends to linger close to the upper target band. Discerning between these two types of central bank's is important especially since central banks tend to emphasize what can be understood as a preference to stay close to the midpoint target. Indeed, the language used by many central banks in specifying their targets provides evidence for this preference. For instance, Chile's Central Bank policy is to “use the necessary instruments to keep annual CPI inflation around 3 percent most of the time, within a tolerance range of plus or minus one percentage point” (see [Banco Central de Chile, 2007](#)). Certainly, the tolerance range is explicitly stated, but the focus — i.e. the target — tends to be the midpoint. With this in mind, I prefer to use the credibility measure specified in eq. (1.2.2).

Robustness: Observed-Inflation-Based Credibility Measures

The second set of measures of central bank credibility in this paper will be defined as a function of the gap between realized annual CPI inflation and the central bank's target. In particular, the first measure of credibility of this kind is defined as the observed year-on-year inflation gap. Formally,

$$CRED_{i,t}^{YoY} = \pi_{i,t}^{yoy} - \bar{\pi}_{i,t} \quad (1.2.3)$$

where $\pi_{i,t}^{yoy}$ is the inflation rate with respect to the same quarter in the previous year. This measure can thought of as an alternative, albeit incomplete, measure of credibility, given that inflation expectations are typically highly correlated with observed inflation. Indeed, the correlation between $CRED^{YoY}$ and $CRED^{EGap}$ for

EM7 countries is about 0.8 and highly significant. This high correlation can be observed in Figure 1.2b.¹⁹

The high correlation between inflation expectations and observed inflation suggests yet another set of credibility measures based on realized inflation. Consider an agent that, early in the year does not have enough information to form accurate end-of-year inflation expectations. One thing the agent can do is use the previous year's realized inflation gap to gauge the central bank's credibility early in the new year. In subsequent quarters, however, as economic information becomes public, it's possible that the agent will form end-of-year inflation expectations that closely correspond to the actual end-of-year inflation. Insofar as we are dealing with countries in which the inflation expectations tend to be close to realized inflation — as it is the case in this paper — we can proxy the later-in-the-year expectations of end-of-year inflation by the observed annual inflation rate. Formally,

$$CRED_{i,t}^{1Q} = \begin{cases} \pi_{i,\tau-1} - \bar{\pi}_{i,\tau-1} & \text{if } t = 1; \\ \pi_{i,\tau} - \bar{\pi}_{i,\tau} & \text{if } t = 2, 3, 4. \end{cases} \quad (1.2.4)$$

$CRED_{i,t}^{1Q}$ is defined so that during the first quarter, the credibility of the central bank is assessed as a function of last year's inflation gap, while during the remaining quarters of the year, the credibility of the central bank is a function of the current year's inflation gap. $CRED_{i,t}^{1Q}$ is a measure that reflect an assessment of the central bank that is a function of current and past performance when information lags are present.

Measuring Foreign Exchange Intervention

Foreign exchange intervention involves a financial operation in which the central bank buys or sells foreign exchange in order to affect the exchange rate (Sarno

¹⁹Refer to Figure A.2 for a figure like 1.2b for all countries in EM13.

and Taylor, 2001). Accordingly, to measure intervention one would like to observe the actual purchases and sales of foreign assets by the central bank. However, as Adler et al. (2015) point out, this data is generally not available. Therefore, as it's usually done in the literature, I proxy FXI by the change in the net foreign asset position of the central bank as reported in its balance sheet. Changes in international reserves, however, may reflect more than just intervention. Accordingly, following Levy-Yeyati et al. (2013), to approximate the changes in reserves that most closely reflect intervention in the FX market, I subtract government deposits at the central bank from the central bank's net foreign assets.²⁰ That is, define net international reserves in U.S. dollars as

$$R_{i,t} = \frac{NFA_{i,t} - \text{Gov. Deposits}_{i,t}}{NER_{i,t}} \quad (1.2.5)$$

where $NFA_{i,t}$ is the central bank's net foreign assets, and $NER_{i,t}$ is the exchange rate defined as the price of a U.S. dollar in terms of the domestic currency. Central banks report their balance sheet items in domestic currency, including the value of their foreign assets and liabilities. To account for this fact, and for comparability purposes, net reserves are converted to US dollars in eq. (1.2.5). It should be noted that the measure in eq. (1.2.5) implicitly assumes that the US dollars is the single currency of denomination of the net FX position of the central bank. This is common practice in the literature since specific data on the composition of the central bank's foreign assets is rarely available. As Adler and Mano (2018) point out, the exact composition of the central bank holdings of foreign currencies is of

²⁰As Levy-Yeyati et al. (2013) note, this correction matters especially in oil producing countries and countries with important privatization programs.

²¹Although the literature relies mostly on changes in reserves to proxy FXI out of necessity, there are well-known reasons why the changes in reserves don't correspond one-to-one with intervention. As Calvo and Reinhart (2002) point out, changes in reserves may reflect fluctuations in valuation, the accrual of interest earnings, and hidden foreign exchange reserve transactions.

secondary importance from an ex ante perspective as long as the reserve currencies held by the central bank are close substitutes of each other.

The first measure of intervention is defined as the ratio of the change in net international reserves to the HP filtered trend GDP in US dollars. This normalization follows [Adler et al. \(2015\)](#) and is meant to prevent endogeneity arising from movements in the US dollar value of GDP. In particular

$$FXI_{i,t}^{RA} = \frac{R_{i,t} - R_{i,t-1}}{GDP_{i,t-1}^{HP\ Trend}} \quad (1.2.6)$$

Beyond comparability, there aren't obvious reasons why one would normalize FXI by GDP. Therefore, for robustness, I define a second measure of intervention in which, as suggested in [Levy-Yeyati et al. \(2013\)](#), the net international reserves are normalized by the monetary base in the previous quarter (measured in US dollars):

$$FXI_{i,t}^{LYS} = \frac{R_{i,t} - R_{i,t-1}}{\frac{MoneyBase_{i,t-1}}{NER_{i,t-1}}} \quad (1.2.7)$$

Commodity Price Shocks

Since the early 2000s, EMEs have faced large terms-of-trade movements, in large part driven by rapid changes in commodity prices. By the end of 2011, for instance, average energy and base metals prices in real terms were three times as high as just a decade before ([IMF, 2015](#)). After 2011, on the other hand, commodity prices fell dramatically, posing fiscal and monetary policy challenges for commodity exporters ([IMF, 2012](#); [IMF, 2018b](#)). Within this reality, EMEs saw their exchange rates change swiftly along with the rapid commodity price swings. The co-movement between commodity prices and the exchange rate observed in the data and studied in the literature ([IMF, 2015](#); [Ferraro et al., 2015](#)) invites the question of whether FXI efforts are successful in the context of commodity price shocks.

With this in mind, the benchmark external variable in this paper will be a country-specific index of commodity export prices. Focusing on these prices seems appropriate given that the EMEs included in this paper are small open economies which take export prices as given in world commodity markets. This implies that — to the extent that world price movements induce changes in the exchange rate — shocks to these prices are exogenous for these countries. Further, with the sole exception of Turkey, the other six countries in EM7 are commodity exporters, and nine of the countries in EM13 are also considered to be commodity exporters. Lastly, even for those EMEs that are not considered to be commodity exporters, their exchange rates display a very high co-movement with a country-specific index of commodity prices (see discussion below).

Certainly, an alternative to these prices is to use terms-of-trade measures that are typically based on export-to-import price ratios. However, I prefer to use commodity export prices over more general terms-of-trade measures for two reasons previously identified in the literature. First, as pointed out in [Chen and Rogoff \(2003\)](#), nominal rigidities and incomplete pass-through prevent standard terms-of-trade measures from capturing contemporaneous shocks that tend to induce immediate changes in the exchange rate, which makes proper identification close to impossible. Second, terms-of-trade measures are typically constructed using unit value indices which are known to bias the representation of export and import price indexes. [Silver \(2009\)](#) documents the various sources of this bias. Among the most important ones are the compositional changes in the quantity and quality mix of the heterogeneous products recorded in customs documents (on which the calculation of export and import unit value indexes is based).

On the other hand, since commodity price indexes are based on observed commodity prices determined in world markets, identification issues and the bias as-

sociated with unit value indexes become less of a concern. With this in mind, I use the index constructed in Gruss (2014). This index is constructed as a weighted average of 45 commodities from the IMF’s Primary Commodity Prices database. In particular, the country-specific indexes are constructed as follows:

$$\Delta \log(CMX_{i,t})_{i,t} = \sum_{j=1}^J \Delta P_{j,t} \cdot \omega_{i,j,\tau} \quad (1.2.8)$$

where $P_{j,t}$ is the logarithm of the relative price of commodity j in month t within year τ (in U.S. dollars and divided by the IMF’s unit value index of manufactured exports), and $\omega_{i,t,\tau}$ is the weight of commodity j in country i for all monthly observations t within year τ . Even though Deaton and Miller (1996) argued for the use of fixed weights in constructing indexes like $CMX_{i,t}$, Gruss (2014) notes that allowing the weights to vary over time is a way of taking into account the fact that the commodity mix traded by many countries has changed significantly over time. Accounting for this is particularly important when the study spans a few decades. As such, the weights used to construct the index are based on three-year rolling averages of export values and lagged on year. The former smooths fluctuations and the latter ensures that the changes in the price index actually reflect changes in the underlying commodity prices instead of endogenous changes in trade volumes (Gruss, 2014).²²

A reason to use country-specific indexes of commodity prices, as opposed to the price of an individual commodity for each country — for instance, the commodity with the highest export share — is that EMEs, even commodity exporters, tend

²²Formally, country i ’s weights for each commodity price are given by

$$\omega_{i,t,\tau} = \frac{1}{3} \sum_{s=1}^3 \frac{x_{i,j,\tau-s}}{\sum_{j=1}^J x_{i,j,\tau-s}}$$

where $x_{i,j,\tau-s}$ denotes the average export value of commodity j by country i between years $\tau - 1$ and $\tau - 3$. See (Gruss, 2014) for more details.

to export not one commodity by baskets of them. This implies that focusing on a single commodity would not accurately represent the overall price movements to which the country is subject (Gruss, 2014). Indeed, Figure 1.3a plots the commodity price index $CMX_{i,t}$ as well as the price index for all commodities, for metals, and for agricultural raw materials taken from the IMF’s Primary Commodity Prices database for four emerging markets in EM13. The figure clearly shows that some indexes (for instance, the agricultural index) underestimates the price changes for most countries most of the time, while other indexes (for example, the metals price index), overestimate the relevant commodity price movements for most countries most of the time.²³

Finally, Figure 1.3b reports commodity price index $CMX_{i,t}$ along with the nominal exchange rate for the same group of countries. The co-movement between these two prices is evident. As mentioned above, with the exception of only four countries (Hungary, Romania, Poland, and Turkey) all other countries in the sample are considered to be commodity exporters. And even in the case of countries like Poland, the co-movement between commodity prices and the exchange rate is evident to the eye. This demonstrates both the strengths of the $CMX_{i,t}$ index and the need to use country-specific indexes.²⁴

Naturally, the correlation observed in Figure 1.3b has received attention in the literature. For instance, Chen et al. (2010) find robust evidence that commodity currencies have predictive power over the exchange rates of commodity exporters. This is a result of the fact that exchange rates are forward looking and commodity price fluctuations represent major terms-of-trade movements for these countries. This implies, as Chen et al. (2010) point out, that when market participants come

²³Refer to Figure A.4 for a figure like 1.3a including all countries in EM13.

²⁴Refer to Figure A.5 for a figure like 1.3b including all countries in EM13.

to expect future commodity price shocks, the expectations is priced into the current exchange rate given the anticipated impact on future export income and exchange rate values. This evidence is corroborated in [Ferraro et al. \(2015\)](#) who report that copper prices have predictive power over the Chilean peso-U.S. dollar exchange rate at daily frequencies.²⁵²⁶

Finally, a different mechanism — and one that is particularly appropriate for IT countries — is studied in [Devereux and Smith \(2018\)](#). In that paper, the authors suggest that increases in commodity prices lead FX market participants to anticipate a tightening of domestic monetary policy in commodity exporting countries. The correlation arises due to the immediate reaction of the exchange rate to the expected change in future policy.

The strong relationship between commodity prices and the exchange rate demonstrates that shocks to commodity prices provide an economically relevant context in which to study the role of credibility in the presence of FXI.

1.2.2 An Interacted Panel Vector Autoregression

The empirical strategy to measure the effects of credibility on the effectiveness of FXI is to use the Interacted Panel Vector Autoregression (IPVAR) framework introduced in [Towbin and Weber \(2013\)](#). Effectively, the model is a panel VAR augmented with interaction terms that allow the VAR coefficients to vary with country character-

²⁵[Ferraro et al. \(2015\)](#) mainly study Canada, but also present results for Norway, South Africa, Australia, and Chile; a set of advanced and emerging market economies typically identified as commodity exporters.

²⁶At monthly and quarterly frequencies, however, [Ferraro et al. \(2015\)](#) report little systematic relation between commodity prices and exchange rates for the set of countries they study. Using lower frequency data, [Cashin et al. \(2004\)](#) have looked at the relationship between commodity currencies and the real exchange rate for a sample of 58 commodity-exporting countries and find evidence of a long-run relationship between the real exchange rate and real commodity prices for about a third of the countries in their sample.

istics. In this paper, it allows the coefficients of the VAR to vary with different degrees of FXI and CBC, thereby allowing me to examine the dynamic response of the endogeneous variables to external shocks conditional on a given level of FXI and degree of CBC.

The General Framework

Formally, a general representation of the IPVAR framework takes the following form:

$$B_{0,it}Y_{i,t} = \tilde{C}_{i,t} + \sum_{l=1}^L B_{l,it}Y_{i,t-l} + \tilde{u}_{i,t} \quad (1.2.9)$$

where $\tilde{C}_{i,t}$ are controls defined as $\tilde{C}_{i,t} = \tilde{C}_i + \sum_{m=1}^M \tilde{C}_m X_{m,it}$ and $B_{l,it}$ is a matrix of coefficients in which the (j, k) scalar element is defined as

$$\beta_{l,it}^{jk} = \alpha_l^{jk} + \sum_{m=1}^M \alpha_{l,m}^{jk} X_{m,it} \quad (1.2.10)$$

where $t = 1, \dots, T$ denotes time and $i = 1, \dots, N$ denote the country. $Y_{i,t}$ is a $q \times 1$ vector of explanatory variables. $\tilde{C}_i$ is a $q \times 1$ vector of country-specific intercepts. The autoregressive coefficients, $\beta_{l,it}^{jk}$, at lag l , capture the dynamics of the system's variables as a function of the interaction terms. The interaction term $X_{m,it}$ is a time-varying, country-specific characteristic that potentially influences the dynamics of the system's variables. This influence is captured in the $\alpha_{l,m}^{jk}$ scalar element. I allow for M such interactions. Without interaction terms, the sum in eq. (1.2.10) would disappear, the autoregressive coefficients would collapse to $\beta_{l,it}^{jk} = \alpha_l^{jk}$, and the model would become a standard panel VAR.²⁷ The interaction terms are also allowed to affect the level of endogenous variables via the $q \times 1$ vector $\tilde{C}_m$. L is

²⁷Equivalently, one can think of the $B_{l,it}$ matrix as composed of two elements

$$B_{l,it} = \tilde{A}_l + \sum_{m=1}^M \tilde{A}_{l,m} X_{m,it}$$

the total number of lags. The residuals in the $q \times 1$ vector $\tilde{u}_{i,t}$ are assumed to be uncorrelated across countries and normally distributed with mean zero and a $q \times q$ constant covariance matrix $\tilde{\Sigma}$.

The contemporaneous relationships among the model variables is captured by the $q \times q$ matrix $B_{0,it}$. This matrix is lower triangular with the number 1 on the main diagonal. The contemporaneous effect of the k th-ordered variable on the j th-ordered variable is given by the term $-\beta_{0,it}^{jk}$, where $\beta_{0,it}^{jk}$ is the (j, k) scalar element of the matrix of contemporaneous coefficients $B_{0,it}$, and is given by

$$\beta_{0,i,t}^{jk} = \alpha_0^{jk} + \sum_{m=1}^M \alpha_{0,m}^{jk} X_{m,it} \quad \text{for } k < j \quad (1.2.11)$$

Accordingly, the coefficients α_0^{jk} and $\alpha_{0,m}^{jk}$ capture the (contemporaneous) marginal contribution of a change in the interaction term $X_{m,it}$ towards $\beta_{0,it}^{jk}$. Given the lower triangular form of $B_{0,it}$ that I impose apriori, $\beta_{0,it}^{jk} = 1$, whenever $k = j$, and $\beta_{0,it}^{jk} = 0$ whenever $k > j$.

IPVAR Specification

To arrive at the particular form of eq. (1.2.9) used in this paper, I assume, as usually done in the literature, that the foreign variables do not depend on the domestic variables. Further, the dynamics of the foreign variables are also assumed to not be influenced by the interaction terms. That is, the dynamics of the foreign variables in the system are independent of the amount of credibility of the central bank in the domestic country and of the amount of FXI conducted by the central bank. The foreign variables, in this sense, are completely exogenous to the domestic country. As such, given the recursive structure of the model, the foreign variables will be

with $\tilde{A}_l$ as a $q \times q$ matrix of autoregressive coefficients at lag l , with α_l^{jk} as its (j, k) scalar element. In this form, the influence of the interaction terms is captured by the $q \times q$ matrix of autoregressive slope coefficients $\tilde{A}_{l,m}$, with $\alpha_{l,m}^{jk}$ as its (j, k) scalar element.

ordered first in the vector of variables $Y_{i,t}$. That is, $Y_{i,t} = (y_{i,t}^* \ y_{i,t})^T$, where $y_{i,t}^*$ and $y_{i,t}$ are the vectors of foreign and domestic variables, respectively. With these assumptions in mind, the recursive IPVAR takes the following representation

$$\begin{pmatrix} B_{0,it}^{11} & 0 \\ B_{0,it}^{21} & B_{0,it}^{22} \end{pmatrix} \begin{pmatrix} y_{it}^* \\ y_{it} \end{pmatrix} = \tilde{C}_{i,t} + \sum_{l=1}^L \begin{pmatrix} B_{l,it}^{11} & 0 \\ B_{l,it}^{21} & B_{l,it}^{22} \end{pmatrix} \begin{pmatrix} y_{i,t-l}^* \\ y_{i,t-l} \end{pmatrix} + \tilde{u}_{i,t} \quad (1.2.12)$$

The matrices $B_{0,it}^{11}$ and $B_{0,it}^{22}$ are lower triangular with 1's in the main diagonal; and $\tilde{B}_{l,it}^{11}$ is also lower triangular, but its main diagonal scalar elements are left unrestricted since they are the autoregressive coefficients on the foreign variables. In particular, given the assumption that the dynamics of the foreign variables are not affected by the country characteristics, the (j, k) scalar element of the $\tilde{B}_{l,it}^{11}$ block is given by

$$\beta_{l,it}^{jk} = \alpha_l^{jk} \quad \text{for } k \leq j \quad (1.2.13)$$

This in no way precludes the foreign variables to dynamically affect the endogenous variables according to country characteristics. Similarly, under the above assumptions on the foreign variables, the (j, k) scalar element of the $B_{0,it}^{11}$ block of coefficients is given by

$$\beta_{0,it}^{jk} = \alpha_0^{jk} \quad \text{for } k < j \quad (1.2.14)$$

Further, the (j, k) scalar element of the $\tilde{B}_{l,it}^{21}$ and $\tilde{B}_{l,it}^{22}$ coefficient matrices are given by²⁸

$$\beta_{l,it}^{jk} = \alpha_l^{jk} + \sum_{m=1}^M \alpha_{l,m}^{jk} X_{m,it} \quad (1.2.15)$$

²⁸As before, thinking in terms of matrices, the lower triangular block of matrices on the right hand side of eq. (1.2.12) can be expressed as

$$\begin{pmatrix} B_{l,it}^{11} & 0 \\ B_{l,it}^{21} & B_{l,it}^{22} \end{pmatrix} = \begin{pmatrix} \tilde{A}_l^{11} & 0 \\ \tilde{A}_l^{21} + \sum_{m=1}^M \tilde{A}_{l,m}^{21} X_{m,it} & \tilde{A}_l^{22} + \sum_{m=1}^M \tilde{A}_{l,m}^{22} X_{m,it} \end{pmatrix}$$

Given the focus on commodity price shocks, the vector $y_{i,t}^*$ is given by

$$y_{i,t}^* = (CMX_{i,t}) \quad (1.2.16)$$

where $CMX_{i,t}$ is the commodity export price index for country i defined in Section 1.2.1.

The domestic variables include macroeconomic indicators that are relevant to IT economies. Further, I include a measure of the monetary policy stance given that the interest is on *sterilized* FXI.²⁹ The vector of domestic variables $y_{i,t}$ is therefore given by

$$y_{i,t} = (MPR_{i,t} \text{ } INV_{i,t} \text{ } GDP_{i,t} \text{ } CPI_{i,t} \text{ } NER_{i,t})^T \quad (1.2.17)$$

where $MPR_{i,t}$ denotes the annualized monetary policy rate. $INV_{i,t}$ denotes real gross fixed capital formation, $GDP_{i,t}$ denotes real gross domestic product, $CPI_{i,t}$ is the consumer price index, and $NER_{i,t}$ is the nominal exchange rate. All variables enter in log first differences, except the monetary policy rate which enters in first differences.

The interactions are $X_{1,it} = FXI_{i,t}$, and $X_{2,it} = CRED_{i,t}$, where $FXI_{i,t}$ is the measure of foreign exchange intervention, and $CRED_{i,t}$ is the measure of CBC defined in Sections 1.2.1 and 1.2.1, respectively. I control for potential interactions between the level of FXI and the degree of CBC. Accordingly, I include a third interaction $X_{3,it} = FXI_{i,t} * CRED_{i,t}$. With this in mind, $M = 3$ in eq. (1.2.12), and the contemporaneous coefficients in matrices $B_{0,it}^{21}$ and $B_{0,it}^{22}$ are given by

$$\beta_{0,it}^{jk} = \alpha_0^{jk} + \alpha_{0,1}^{jk}FXI_{i,t} + \alpha_{0,2}^{jk}CRED_{i,t} + \alpha_{0,3}^{jk}FXI_{i,t} * CRED_{i,t} \quad \text{for } k < j \quad (1.2.18)$$

²⁹Unsterilized FXI — the situation in which FX purchases are not matched by equal reductions in the money supply — would have an obvious depreciation effect on the exchange rate.

Similarly, the autoregressive coefficients of the $\tilde{B}_{l,it}^{21}$ and $\tilde{B}_{l,it}^{22}$ matrices are given by

$$\beta_{l,it}^{jk} = \alpha_l^{jk} + \alpha_{l,1}^{jk}FXI_{i,t} + \alpha_{l,2}^{jk}CRED_{i,t} + \alpha_{l,3}^{jk}FXI_{i,t} * CRED_{i,t} \quad (1.2.19)$$

To analyze the effect of intervention on the exchange rate I first restrict $\alpha_{l,2}^{jk} = \alpha_{l,3}^{jk} = 0$, for every l . Then, to analyze the effect of central bank credibility on the dynamics of the exchange rate I set $\alpha_{l,1}^{jk} = \alpha_{l,3}^{jk} = 0$, for every l . Finally, to analyze how the effect of central bank credibility interacts with the effect of FXI on the exchange rate I leave all coefficients in (1.2.18) and (1.2.19) unrestricted.

The main difference between the IPVAR and a panel VAR is, as [Abbritti and Weber \(2018\)](#) point out and as one can observe in eq. (1.2.12), that the regressand is regressed not only on the lagged regressors, but also on the regressors interacted with the country characteristics. In this case, with the amount of FXI conducted and with the credibility of the central bank. Fundamentally, this is what allows me to analyze the IRFs at various combinations of FXI and degrees of central bank credibility.

The classical concern on FXI studies is the endogeneity of the FXI decision. This usually refers to the endogeneity of FXI with the exchange rate, but not with other macroeconomic variables. A potential endogeneity of FXI with respect to other macroeconomic variables needs to be addressed since in the IPVAR specification above FXI is not included as an endogeneous variable. That is, FXI is not allowed to respond to other variables. Yet it is allowed to affect the level and the dynamics of all variables in the system. A priori, given the nature of FXI, one should not expect that macroeconomic variables other than the exchange rate to trigger an intervention decision, but one needs to be sure. One general way to deal with endogeneity issues is to lag the variable of interest, but in this case that won't do since I want to include

a contemporaneous measure of FXI in the interaction terms. The reason is that interventions occur contemporaneously with exchange rate movements. Lagging the FXI measure would unnecessarily restrict the notion of intervention given a shock. Including a contemporaneous measure of FXI, however, requires an explicit assumption that FXI will not be endogenous with business cycle variables other than the exchange rate. To formalize this assumption I estimate the following equation for the post-IT adoption period of the countries in my sample:

$$\begin{aligned}
 FXI_{i,t} = & \eta_0 + \eta_2 MPR_{i,t} + \eta_3 INV_{i,t} + \eta_4 GDP_{i,t} \\
 & + \eta_5 CPI_{i,t} + \eta_6 NER_{i,t} + \eta_7 CMX_{i,t} + \epsilon_{i,t}
 \end{aligned} \tag{1.2.20}$$

where $FXI_{i,t}$ is either $FXI_{i,t}^{LYS}$ or $FXI_{i,t}^{RA}$. The results can be seen in Table 1.1. They show that, perhaps as one would expect, an appreciation (depreciation) of the exchange rate, that is a decrease (increase) in the exchange rate, triggers the accumulation (selling) of foreign exchange reserves. This is what one would expect when the central bank is trying to curb an appreciation (depreciation). Further, this coefficient is highly significant and is generally robust to variations in the specification. Besides the exchange rate, no other macroeconomic variable appears to trigger an intervention in a statistically significant way consistently across specifications and country groups. The estimations do show, however, that real GDP seems to be correlated with reserve accumulation when the estimation is conducted using the $FXI_{i,t}^{LYS}$ measure, but this only occurs in one specification. CPI inflation also appears to be correlated with reserve accumulation for the group of EM7 countries, but the fact that the significance on the exchange rate is lost in those same specifications tells us that CPI inflation could be picking up some of the correlation from the exchange rate. This, however, would be taken care of when the IPVAR is estimated. At any rate, overall, the results in Table (1.1) point to the conclusion

that assuming that FXI is fundamentally triggered by innovations in the exchange rate is adequate.

Even with this in mind, estimation of eq. (1.2.12) may still be subject to some degree of the endogeneity problem that tends to conceal the effect of FXI on the exchange rate, as it happens in other studies. In that case then, the effect of FXI found in this paper may be considered a lower bound of the potential effect that intervention may have on the exchange rate.

Finally, the inclusion of CPI inflation in eq. (1.2.12) is a way to deal with the endogeneity of the measure of CBC with other business cycle variables. At any rate, it is perhaps impossible to argue that the measure of CBC used in this paper — the inflation expectations gap or the observed inflation gap — is not endogenous with other business cycle variables. For this reason, the measures of CBC used in this paper will be lagged one quarter in all estimations.

Estimation and Identification

I estimate the model in eqs. (1.2.12), with (1.2.18) and (1.2.19) included, using OLS. Since, by construction, the errors are uncorrelated across equations, it's possible to estimate (1.2.12) equation by equation. Once the coefficients in (1.2.18) and (1.2.19) are estimated, they can be used to evaluate the $\beta_{0,it}^{jk}$ and $\beta_{l,it}^{jk}$ coefficients for any combination of FXI and degree of central bank credibility one desires. Then, using these $\beta_{0,it}^{jk}$ and $\beta_{l,it}^{jk}$ coefficients I can analyze the dynamic response of the endogenous variables to a given shock for the particular combination of FXI and CBC chosen. I use one lag based on the Schwartz Criterion.

Identification of the commodity price shock is achieved recursively by imposing a small open economy assumption on the countries in the sample. That is, by ordering the commodity export price index first, and assuming the countries in

the sample are small enough to have no impact on the prices of the commodities they export. Effectively, the assumption is that commodity export prices are contemporaneously unaffected by the other variables in the system. This identifying assumption amounts to constraining the matrix $B_{0,it}^{11}$ to be lower triangular. Since the focus is on the commodity export price shock, the ordering of the other variables in the system is immaterial. In this sense, the model is partially identified.

An implication of this framework is that the IRFs are non-linear functions of the OLS estimates. Accordingly, analytical errors that rely on first order asymptotics may not be accurate (see [Towbin and Weber, 2013](#)). To deal with this concern, bootstrapped confidence intervals are reported as proposed by [Runkle \(1987\)](#).

1.2.3 Data

The sample encompasses the period 1999Q1-2016Q4. Two sets of countries are considered based on whether or not inflation expectations data is publicly available, which conditions my ability to construct expectations-based CBC measures as described in Section [1.2.1](#). The set of countries for which inflation expectations data is publicly available includes Brazil, Chile, Colombia, Guatemala, Mexico, Peru, and Turkey. These are referred to as EM7. Robustness checks and the estimations using CBC measures based on observed inflation are conducted by expanding the EM7 set to include Hungary, Indonesia, Philippines, Poland, Romania, and Thailand. The expanded set is referred to as EM13. All the EMEs included in EM7 and EM13 are countries with formal IT frameworks. Whether a country is considered to use the IT framework was based on the classification provided in the IMF's 2016 Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER). Only countries with at least 10 years (40 quarters) under the IT framework were included. This

ensures enough data coverage under *de jure* floating exchange rates.³⁰ Since the focus is on analyzing the effectiveness of FXI under the IT regime and the measures of CBC used in this paper are a function of the central bank’s inflation target, the sample for any given country is restricted to its post-IT adoption date. This implies that the sample is unbalanced.

Details and summary statistics on the countries included are summarized in Table A.1. Macroeconomic data come mainly from the IMF’s International Financial Statistics (IFS), the OECD’s Quarterly National Accounts, and the Federal Reserve of St. Louis’ FRED. The data to construct the FXI measure come from the IFS’ Central Bank Survey and from central banks’ websites. The inflation targets used in the construction of the credibility measure were obtained directly from the countries’ central banks’ websites, and the inflation expectations data are obtained from surveys of inflation expectations conducted by the central banks in the sample. The commodity export price index is obtained from the database constructed by Gruss (2014). Details on the data sources are summarized in Table A.2.

1.3 Results

This section presents the results by analyzing the impulse responses of the endogenous variables to a given shock in commodity prices. As it was previously mentioned, inflation expectations data is publicly available only for a sample of seven countries. Accordingly, the expectations-based credibility measures defined in Section 1.2.1 are only available for these countries. Recall that these set of countries are referred to as EM7 and it includes Brazil, Chile, Colombia, Guatemala, Mexico, Peru, and

³⁰Accordingly, the cutoff IT adoption year for a country to be included in the sample is 2006. Sweden was excluded since they started using negative rates in 2014. South Africa was not included due to limited data availability.

Turkey. Subsections 1.3.1, 1.3.2, and 1.3.3, present the results using this sample. Subsection 1.3.1 presents the effects of FXI on exchange rate dynamics, subsection 1.3.2 presents the effects of expectations-based CBC on the dynamics of the economy, and subsection 1.3.3 presents the results of the interaction between FXI and expectations-based CBC.

Later, in Subsection 1.3.4, I present the robustness checks which rely upon expanding the sample of countries by adding Hungary, Indonesia, Philippines, Poland, Romania, and Thailand to the EM7 group. Recall that these are referred to as EM13. Since for these additional countries, inflation expectations data is not publicly available, I use measures of CBC based on observed inflation as detailed in Section 1.2.1. For consistency, subsection 1.3.4 presents the effects of FXI on the exchange rate by rerunning the estimations using the EM13 sample of countries. Then, subsection 1.3.4 presents the effect of CBC on the dynamics of the exchange rate using the observed-inflation-based credibility measures using both the EM7 and EM13 samples, and lastly subsection 1.3.4 shows the effect of the interaction between FXI and observed-inflation-based CBC.

1.3.1 Foreign Exchange Intervention

Since, as Levy-Yeyati et al. (2013) noted, interventions have been aimed, in most cases, at fighting appreciations (especially in recent years), the analysis will be focused on the dynamic response of the economy given a positive commodity exports price shock — a shock that tends to induce an exchange rate appreciation. This *fear of appreciation* has become more prevalent since the early 2000s (Levy-Yeyati et al., 2013), which coincides with the adoption of inflation targeting and *de jure* floating exchange rate arrangements of most IT emerging markets.

Figure 1.4 plots the cumulative response of the nominal exchange rate to a 10 percent positive commodity export price shock under varying intensities of FXI. Panels 1.4a and 1.4b use the FXI measure $FXI_{i,t}^{RA}$ and $FXI_{i,t}^{LYS}$, respectively. The first and second columns in each panel show the response of the nominal exchange rate under heavy intervention and light intervention, respectively. The third column reports the difference between the point estimates of the exchange rate response under heavy and light intervention, together with its corresponding confidence band. The impulse responses under heavy and light FXI are calculated by evaluating the coefficients in eqs. (1.2.18) and (1.2.19) at two levels of FXI intensity roughly corresponding to an idea of heavy and light intervention. Since the FXI measures are allowed to be positive or negative, heavy and light intervention correspond, as a benchmark, to the 80th and 50th percentile of the FXI distribution, respectively. Accordingly, for $FXI_{i,t}^{RA}$, heavy intervention amounts to change in net reserves of 1.3 percent of GDP, and light intervention corresponds to a change in net international reserves of 0.7 percent of GDP. While for $FXI_{i,t}^{LYS}$, heavy intervention amounts to change in net reserves of 16.6 percent of the monetary base, and light intervention corresponds to a change in net international reserves of 1.7 percent of the monetary base.

The figure clearly shows that, given the shock, the nominal exchange rate appreciates less under heavy intervention than under light intervention. Using the $FXI_{i,t}^{RA}$ intervention proxy, the estimations suggest that the nominal exchange rate appreciates by about 0.4 and 1.2 percentage points less under heavy than under light intervention. Similarly, using $FXI_{i,t}^{LYS}$, the exchange rate appreciates by about 0.4 and 1.5 percentage points less under heavy FXI than under light FXI. The third col-

umn clearly shows that these differences are statistically significant.³¹ These results provide evidence that FXI is effective at curbing appreciation pressures in inflation targeting EMEs in the context of commodity export price shocks. Specifically, the results using the $FXI_{i,t}^{RA}$ intervention proxy suggest that to induce, on average, a 1 percent depreciation of the domestic currency, the central bank needs to purchase foreign currency in the amount equivalent to 0.75 percent of GDP.

In general, these results are in line with the findings in Aizenman et al. (2012), who find that FXI is effective at curbing appreciations driven by commodity price shocks. Importantly, no other macroeconomic indicator shows any statistically significant difference in its dynamic behavior under heavy and light FXI. This is what one would expect if one is correctly capturing the change in international reserves that mostly reflects intervention in the foreign exchange market. The interested reader is referred to Figures A.6 and A.7 in the Appendix for the response of all the endogenous variables using the $FXI_{i,t}^{RA}$ and $FXI_{i,t}^{LYS}$ measures, respectively.

1.3.2 Expectations-based Central Bank Credibility

The cumulative response of the nominal exchange rate, the monetary policy rate, and the CPI inflation for varying degrees of central bank credibility are shown in Figure 1.5. Panels 1.5a and 1.5b correspond to the use of the $CRED^{EGap}$ and $CRED^{LLR}$ expectations-based credibility measures, respectively. As before, the first and second columns in each panel show the response of the endogenous variables under high and low central bank credibility, respectively. The third column reports the difference between the point estimates under high and low central bank credibility, together with its corresponding confidence band. The impulse response

³¹Statistical significance here refers to the fact that the 68 percent (1 standard deviation) bootstrapped confidence bands do not contain zero.

functions at different degrees of central bank credibility are calculated by evaluating the coefficients in eqs. (1.2.18) and (1.2.19) at two levels of central bank credibility roughly corresponding to a notion of high and low central bank credibility. Since $CRED^{EGap}$ is allowed to be positive or negative, a smaller inflation expectations gap implies a higher degree of central bank credibility — given that this corresponds to a higher degree of anchoring of inflation expectations. Therefore, the high and low central bank credibility in this case correspond, as a benchmark, to the 50th and 80th percentile of the $CRED^{EGap}$ distribution, respectively. Accordingly, high central bank credibility using the $CRED^{EGap}$ measure amounts to an inflation expectations gap of 0.6 percent, and low central bank credibility corresponds to an inflation expectations gap of 1.4 percent. On the other hand, since $CRED^{LLR}$ is an index that goes from 0 to 1 — with a higher index implying a higher degree of central bank credibility — high and low central bank credibility in this case correspond to the 80th and 20th percentile of the $CRED^{LLR}$ distribution, respectively. Accordingly, high central bank credibility using the $CRED^{LLR}$ measure amounts to an index of 0.98, and low central bank credibility corresponds to an index of 0.36.

The endogenous variables in both panels in Figure 1.5 display the same dynamics. Given the commodity export price shock, which puts both appreciation as well as inflationary pressures, the nominal exchange rate appreciates less when the central bank has a higher degree of credibility. The mechanism is driven by the fact that under lower CBC — the situation in which inflation expectations are less anchored — key macroeconomic indicators like CPI inflation and output react more strongly to the shock, thereby inducing the central bank to raise its policy interest rate more aggressively than in a situation in which the central bank has a higher degree of credibility. The relatively higher interest rate increase in the low credibility case leads to a higher appreciation of the nominal exchange rate. The results using the

$CRED^{EGap}$ credibility proxy suggest that a loss of credibility in the form of a 1 percent increase in the inflation expectations gap, ultimately leads to a 1.13 percent appreciation of the exchange rate.

Equivalently, these results show that when the central bank enjoys of higher levels of credibility — as measured by the anchoring of inflation expectations — the exchange rate appreciates less given a shock, and this is a consequence of the fact that more credible central banks needs to raise interest rates by a lower amount than less credible central banks, given that CPI inflation and output reacted less aggressively to the shock in the first place. The result in this subsection is related to the findings reported in chapter 3 of IMF (2018b), which studies the relationship between central bank credibility and the procyclicality of monetary policy in inflation targeting countries. That chapter reports that central banks with lower credibility engage in more procyclical monetary policy, raising interest rates in the face of unfavorable terms-of-trade shocks. The authors of the chapter interpret the procyclicality as a rational response of the central bank to poorly anchored inflation expectations.³²

It's important to stress the fact that under higher central bank credibility, not only CPI inflation reacts more strongly to the shock, but so does output growth. The reader is referred to Figures A.8 and A.9 in the Appendix for the response of all variables in the system using the $CRED^{EGap}$ and $CRED^{LLR}$ measures respectively. It would be a mistake, however, to conclude that lower central bank credibility is desirable insofar as it leads to higher output growth when a positive shock occurs. First, the difference in output growth between high and low central bank credibility may not be consider economically significant — the point estimate is 0.1 percent. Second, and perhaps more importantly, this is simply a reflection of the fact that

³²The chapter, however, stops short of reporting the effects of credibility on the exchange rate response. Further, that chapter does not touch on the subject of foreign exchange interventions.

lower central bank credibility leads, in general, to more aggressive responses from the endogenous variables. Indeed, given the linearity of the VAR specification, we know that given a negative shock, output growth would drop by a larger amount under low credibility. This is not a desirable outcome.

1.3.3 FXI and Expectations-based CBC

I now investigate the response of the nominal exchange rate under different amounts of FXI conditional on the level of central bank credibility. Figure A.10 plots the cumulative response of the nominal exchange rate, the monetary policy rate, and CPI inflation under different combinations of FXI intensity and degrees of CBC. The first and second columns from the left report the dynamics of the endogenous variables under heavy FXI; they differ in that the first column considers the case of high CBC, while the second column considers the case of low CBC. Similarly, the fourth and fifth columns report the response of the economy under light FXI; again, they differ in that the fourth column reports the dynamics under high CBC, while the fifth column reports the dynamics under low CBC. The third and sixth column report the difference between the first and second column, and between the fourth and fifth column, respectively. The IRFs are calculated using the $FXI_{i,t}^{RA}$ as a proxy for intervention, and $CRED^{LLR}$ as the credibility proxy. The level of heavy and light intervention, and of high and low CBC are those discussed in sections 1.3.1 and 1.3.2.

Overall, Figure 1.6 shows that the effect of FXI can be undone by the degree of credibility of the central bank, regardless of the intensity of the intervention. In general, for a given intensity of FXI — whether heavy or light intervention — the exchange rate appreciates more when the central bank has lower degrees of

credibility. In particular, the results show that if a central bank engages in heavy FXI, being less credible is detrimental to the intervention efforts. Columns (1) and (2) show that, conditional on engaging in heavy intervention, the exchange rate appreciates by 1.5 percent under high CBC and by 3 percent under low CBC. Indeed, the third column from the left, labeled Difference (1) - (2), shows that conditional on engaging in heavy FXI, the exchange rate appreciates by about 1.5 percentage points less when the central bank enjoys of higher credibility. Qualitatively, the same result is obtained when the central bank engages in light FXI. In particular, conditional on engaging in light intervention in foreign exchange markets, the exchange rate appreciates by about 2.2 percent under high CBC, while it appreciates by about 3.7 percent under low CBC. Once again, the difference, reported in the sixth column is about 1.5 percentage points. This implies that having higher credibility yields a sort of *credibility premium* — the difference in exchange rate appreciation between high and low credibility for a given FXI intensity (reported in columns 3 and 6 from the left in Figure 1.6).

The results point to the conclusion that the credibility of the central bank matters when trying to curb exchange rate pressures. The mechanism behind these results follows the same logic as discussed in section 1.3.2. Following the shock, CPI inflation increases more when inflation expectations are less anchored — when CBC is low — than when they are well anchored — when CBC is high (compare columns one and two, and four and five in row two of Figure 1.6). This triggers a more aggressive monetary policy response in the form of higher interest rates than otherwise would be required under higher level of credibility (compare columns one and two, and four and five in row three of Figure 1.6). This puts a fresh source of appreciation pressure on the exchange rate which ultimately undermines part of the benefit of intervening in foreign exchange markets.

Figure 1.7 plots the dynamics of the exchange rate using the different measures of FXI and expectations-based credibility measures defined in sections 1.2.1 and 1.2.1. The figure shows that, qualitatively, the results are robust to different combinations of FXI and credibility measures — that is, that the *credibility premium* on exchange rate dynamics is robust. Panel 1.7a plots the exchange rate response from Figure 1.6. For a figure similar to Figure 1.6, which plots the exchange rate response along with the CPI inflation response and the monetary policy reaction, corresponding to panels 1.7b, 1.7c, and 1.7d, the reader is referred to Figures A.10, A.11 and A.12 in the Appendix.

How costly can low central bank credibility be in terms of foreign exchange intervention?

The point estimates of the exchange rate response in columns (2) and (3) of Panel 1.7a, suggest that a central bank with low credibility and that engages in heavy FXI can end up with an appreciation that is quantitatively similar to that of a highly credible central bank that conducts only light FXI.

I now formalize this notion, and obtain an approximation of how costly low credibility can be in terms of reserve accumulation. To facilitate the discussion, Figure 1.8 reproduces the exchange rate response to a positive 10 percent commodity export price shock under various combinations of FXI intensities and degrees of CBC originally displayed in Figure 1.6. Figure 1.8, however, displays the various combinations in a different order and plots IRF differences not displayed in Figure 1.6. Column (A) displays the exchange rate response to the shock when the central bank engages in light FXI and has high credibility. Given that light FXI corresponds to an accumulation of international reserves equivalent to 0.7 percent of GDP and that high central bank credibility corresponds to a positive inflation expectations

gap of 0.6 percent, this can be considered the baseline scenario. Now, consider column (B), in which the central bank still has high credibility but engages in heavy FXI. The third column, labeled (A) - (B), plots the difference between these two cases. As previously discussed, the difference shows that heavy intervention allows the central bank to depreciate the currency, resulting in an exchange rate that appreciates less, given the shock. Now suppose that the central bank still engages in heavy FXI, but loses credibility. This scenario is shown in column (C). The fifth column, labeled (B) - (C), display the associated difference, and shows that losing credibility is detrimental to the heavy intervention effort of the central bank. In particular, a central bank that engages in heavy FXI sees the exchange rate appreciate 1 percentage point less when it has higher credibility than when it does not.

Finally, we can answer the question: how costly can lack of credibility be in terms of reserve accumulation? To answer this, compare the dynamics of the exchange rate under heavy FXI and low CBC to the dynamics of the exchange rate under the baseline scenario of light FXI and high CBC. That is, observe the difference between the two point estimates of columns (A) and (C), displayed in the sixth column of Figure 1.8. This shows that there is no difference in the cumulative response of the exchange rate under these two cases. What this implies is that the central bank needs to engage in heavy FXI only to overcome the extra appreciation pressure posed by the low credibility and the associated more aggressive interest rate increase. In this manner, under the assumption that the FXI effort was aimed at curbing the appreciation pressure posed by the commodity price shock, the results clearly show that low CBC can completely undermine this effort. That is, low CBC completely cancels out the effect of FXI in this exercise. Now, note that going from low to high CBC implies a deterioration of the inflation expectations

gap by 0.8 percentage points, and going from light to heavy intervention implies an increase of net international reserves in the amount of 0.6 percent of GDP. Since these two effects cancel out, this implies that the appreciation effect (through higher interest rates) of a loss of credibility reflected by a 1 percentage point increase in the inflation expectations gap, can cancel out the depreciation effect of a purchase of foreign currency equivalent to 0.75 percent of GDP. Given that the average net international reserves holding by the countries studied in this paper during the sample period was 10 percent, the results suggest that a loss credibility can be very costly in terms of reserve accumulation.

1.3.4 Robustness

As was mentioned earlier, the main results of the paper, those reported in subsections 1.3.1, 1.3.2, and 1.3.3 use a sample of 7 countries, EM7, for which inflation expectations data is publicly available. In this subsection, I expand the sample to 13 EMEs by adding Hungary, Indonesia, Philippines, Poland, Romania, and Thailand to the EM7 group. I first show that the effect of FXI on the exchange rate is robust to expanding the sample size. Then, I use the CBC measures based on observed-inflation described in Section 1.2.1 to show that the effect of expectations-based CBC on the exchange rate is robust to these alternative CBC measures and to expanding the sample size. Finally, I show that the notion of the credibility premium is qualitatively robust to the alternative CBC measures and to expanding the sample size.

Foreign Exchange Intervention, Extended Sample Size

I first provide evidence that extending the sample size from EM7 to EM13 one obtains the same qualitative results regarding the effectiveness of FXI on curbing appreciation pressures.

Figure 1.9 plots the cumulative response of the nominal exchange rate to a 10 percent positive commodity export price shock under varying intensities of FXI for the EM13 sample of countries, in the same manner that Figure 1.4 did for the EM7 set of countries. The figure once again shows that under higher levels of FXI, the nominal exchange rate appreciates less following the shock. Both measures of FXI are robust to extending the sample size. The figure shows that almost doubling the amount of countries analyzed, one obtains results that are qualitatively equivalent to the ones obtained before, and that are quantitatively very close to the ones obtained before as well. Indeed, the third column of Panel 1.9a shows that the exchange rate appreciates between 0.4 and 1 percentage points less under heavy FXI than under light FXI. Similarly, the third column of Panel 1.9b shows that the exchange rate appreciates between 0.2 and 0.8 percentage points less under heavy FXI than under light FXI.

Observed-inflation-based CBC

As was mentioned in section 1.2.1, the relationship between inflation expectations and observed inflation allows me to explore the role of CBC using measures based on realized inflation. Doing so, I can directly observe whether the results are robust to the alternative measures of CBC and, additionally, to extending the sample size.

For comparability, I first verify whether the results are robust to using the measures of CBC based on observed inflation while keeping the set of countries intact. In Figure 1.10, Panels 1.10a and 1.10b, I plot the cumulative response of the nominal

exchange rate, the monetary policy rate, and CPI inflation for varying degrees of observed-inflation-based CBC for the EM7 set of countries. The dynamics of the endogenous variables are equivalent to the findings reported in Figure 1.5, which used expectations-based CBC measures. Once again, under low CBC, the monetary policy authority needs to raise interest rate more aggressively given the larger response of CPI inflation to the shock. As a result, the nominal exchange rate appreciates more under low CBC.

Now I extend the sample from the EM7 set of countries to the EM13 set of countries. The results are reported in Figure 1.11, in Panels 1.11a and 1.11b. As is evident, the dynamics are equivalent to those reported before in Panels 1.10a and 1.10b, and to those reported in Figures 1.5, which used expectations-based CBC measures. The mechanism is the same as that reported in subsection 1.3.2. Quantitatively, however, the point estimates and the possible range of values for the effect that CBC has on the exchange rate are smaller in magnitude from those estimated using expectations-based CBC measures. This makes sense given that the CBC measures based on observed-inflation, although a close proxy, don't contain all the information about the credibility of a central bank that expectations-based CBC measures may contain.

FXI and Observed-inflation-based CBC, Extended Sample

I now report the results using the extended sample of countries and the CBC measures based on observed inflation. Figure 1.12 plots the cumulative response of the nominal exchange rate, the monetary policy rate, and CPI inflation under different combinations of FXI intensity (using the FXI^{LYS} measure) and degrees of central bank credibility (using $CRED^{YoY}$) in the same manner as Figure 1.6. As Figure 1.12 shows, the results reported in Figure 1.6 are qualitatively robust to changing

the CBC measure from one that is based on the inflation expectations gap to one that is based on the realized inflation gap, and to extending the sample of countries under consideration. That is, as before, for a given amount of intervention, the exchange rate appreciates less when the central bank enjoys of a higher degree of credibility.

The mechanism behind this result is the same as before: lower CBC induces a more aggressive monetary policy response. That is, interest rates need to be increased more under lower CBC to compensate for the more aggressive reaction of CPI inflation to the shock. This puts a fresh source of appreciation pressures on the exchange rate.

Quantitatively, the *credibility premium* as measured by the difference between the point estimates of the exchange rate under high and low CBC, given a certain amount of FXI, is once again economically significant, but lower in magnitude than in previous estimations. Indeed, under heavy FXI, the point estimate in column three of Figure 1.12 shows that the *credibility premium* stands at almost 0.4 percent. In turn, under light FXI, the point estimate in column six of the same figure shows that the *credibility premium* stands at about 0.2 percent. These estimates are lower than those obtained using expectations-based CBC measures, but as it was mentioned before, they may simply reflect the fact that CBC measures based on observed inflation don't contain all information necessary to properly measure the credibility of a central bank. Nevertheless, these are informative measures, and they provide the same qualitative conclusion. Indeed, these differences show that within the context of intervention in foreign exchange markets, the role of CBC is an important, especially when there is some degree of tension between the intervention and other policy objectives.

Using different combinations of the FXI measures (FXI^{RA} and FXI^{LYS}) and the observed-inflation-based CBC measures ($CRED^{YoY}$ and the $CRED^{1Q}$), one obtains equivalent results. The reader is referred to Figures A.17, A.18, and A.19 for the results using the remaining combinations of these measures.

1.4 Conclusion

Significant exchange rate pressures — brought forth by large terms-of-trade shocks and significant international capital flows — have induced central banks in EMEs to intervene in foreign exchange markets. These interventions have taken place even in countries with formal inflation targeting regimes in which, in principle, the exchange rate is supposed to freely float. This has led to an intense debate on the merits and viability of foreign exchange interventions in IT EMEs. Normative questions aside, the reality has been that central banks in these countries have actively intervened in foreign exchange markets given the crucial role that the exchange rate plays in their economies.

Even with this in mind, given that the primary objective of the IT framework (and therefore the main mandate of IT central banks) is price stability, there have been occasions in which central banks have engaged in foreign exchange interventions efforts that were not consistent with the monetary policy stance. The difficulties posed by this kind of policy inconsistency could be made worse insofar as the monetary policy stance needs to be more aggressive given certain institutional characteristics. In particular, lack of central bank credibility — as measured by the anchoring of inflation expectations — could undermine the effectiveness of foreign exchange intervention efforts to the extent that less credible central banks need to

increase interest rates more aggressively while trying to fight simultaneous appreciation pressures.

This paper attempts to quantify to what extent the credibility of the central bank matters in this regard. In particular, using an interacted panel vector autoregression framework and a set of seven inflation targeting emerging markets, I first test whether FX interventions can curb exchange rate pressures in these economies. Then, I attempt to capture the effect of central bank credibility on the effectiveness of FX interventions.

I find that, when the central bank fights simultaneous appreciation and inflationary pressures driven by commodity price shocks, FX intervention indeed leads to less exchange rate appreciation, but that lack of credibility can undermine a central bank's FX intervention effort. The mechanism behind this result is that less credible central banks need to increase interest rates more aggressively to stabilize inflation. This undermines the simultaneous effort to depreciate the currency by inducing a new source of appreciation pressure on the exchange rate.

In fact, the results suggest that the appreciation effect of a loss of credibility in the form of a 1 percentage point increase in the inflation expectations gap can completely cancel out the depreciation effect of a purchase of foreign currency equivalent to 0.75 percent of GDP. Equivalently, an IT EME central bank needs to accumulate international reserves in the amount of 0.75 percent of GDP to overcome the appreciation effect of a 1 percentage point increase in the inflation expectations gap. Given that the average amount of international reserves held by the IT EMEs included in this paper is 10 percent of GDP throughout the sample period, the results suggest that overcoming a loss of credibility can have a large impact on the international reserves.

These results show that within the context of intervention in foreign exchange markets, the role of central bank credibility is a crucial one, especially when other policy objectives need to be addressed, and when there is some degree of tension between the intervention and price stability objectives.

There are many benefits to having well-anchored inflation expectations and high policy credibility, and this paper suggests another one. The results presented here offer further incentive for policymakers to focus on increasing transparency and devising better communication strategies with the aim of improving the credibility of monetary policy. It is typically understood that credible central banks need to do less to deliver price stability. The results in this paper suggest that credible policy can also more easily deliver exchange rate stability, and that losing credibility can be costly.

Table 1.1: FXI and Business Cycle Variables

VARIABLES	(1) FXI^{LYS}	(2) FXI^{LYS}	(3) FXI^{RA}	(4) FXI^{RA}	(5) FXI^{LYS}	(6) FXI^{LYS}	(7) FXI^{RA}	(8) FXI^{RA}
Exchange Rate	-0.217 (0.195)	0.0400 (0.245)	-0.0600** (0.0266)	-0.0473 (0.0354)	-0.480*** (0.137)	-0.374** (0.169)	-0.0772*** (0.0176)	-0.0674*** (0.0222)
Policy Rate		32.35 (121.3)		-1.565 (17.52)		-101.5 (87.84)		-15.77 (11.52)
Investment		0.429 (0.269)		0.0267 (0.0389)		0.183 (0.153)		0.0182 (0.0201)
Real GDP		1.421 (1.405)		0.0969 (0.203)		2.023* (1.200)		0.136 (0.157)
CPI Inflation		-3.020** (1.314)		-0.371* (0.190)		-1.212 (0.781)		-0.159 (0.102)
Comm. Exp. Price		16.14 (11.72)		0.653 (1.693)		5.759 (8.784)		0.356 (1.152)
Constant	0.762 (9.287)	3.313 (9.456)	0.278 (1.262)	0.629 (1.367)	3.012 (8.821)	4.027 (8.852)	0.482 (1.130)	0.528 (1.160)
Observations	383	343	383	343	722	674	722	674
R-squared	0.042	0.091	0.030	0.048	0.058	0.083	0.052	0.063
Num. of countries	7	7	7	7	13	13	13	13
Country Group	EM7	EM7	EM7	EM7	EM13	EM13	EM13	EM13
Country FE	YES	YES	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES	YES	YES

Note: All variables enter the estimation in log first differences, except the monetary policy rate which enters the estimation in first differences.

Standard errors in parentheses
 *** p<0.01, ** p<0.05, * p<0.1

Figure 1.1: Exchange Rates and Exchange Rate Management, post IT adoption.

Note: Panel (a) shows an index of the nominal exchange rate (2005Q1 = 100), defined as domestic currency per U.S. dollar (so an increase represents a depreciation), for the following countries: Brazil (BRA), Chile (CHL), Colombia (COL), Guatemala (GTM), Hungary (HUN), Indonesia (IDN), Mexico (MEX), Peru (PER), Philippines (PHL), Poland (POL), Romania (ROM), Thailand (THA), and Turkey (TUR). Panel (b) plots an index of exchange rate management for a set of IT and non-IT countries. The countries included are those in panel (a) plus The Dominican Republic (DOM), Russia (RUS), Croatia (HRV), Costa Rica (CRI), Uruguay (URY), Nicaragua (NIC), Honduras (HND), and Bolivia (BOL). The index is calculated as $\xi = \sigma_{\Delta Reserves} / (\sigma_{\Delta Reserves} + \sigma_{\Delta NER})$, where $\sigma_{\Delta Reserves}$ and $\sigma_{\Delta NER}$ are the standard deviations of changes in net international reserves (normalized by HP trend GDP), and of changes in the nominal exchange rate, respectively. Therefore, ξ ranges from 0 (pure float) to 1 (a peg). The sample period runs from 1999-2016; where the sample for each country starts after the adoption of IT.

Figure 1.2: Inflation Expectations, and Inflation gaps, selected countries.

(a) *Expected and Observed Inflation* (b) *Credibility, $CRED^{EGap}$ and $CRED^{YoY}$*

(c) *Credibility Index: $CRED^{LLR}$*

Note: Panel (a) plots the inflation targets and realized inflation for a subset of EM7 countries. Panel (b) plots the expectations-based credibility measure $CRED^{EGap}$ and the observed-inflation-based credibility measure $CRED^{YoY}$. Finally, Panel (c) plots the expectations-based credibility measure $CRED^{LLR}$. This index falls between 0 (implying total loss of credibility) to 1 (implying full credibility).

Figure 1.3: Commodity Price Indexes.

(a) *Country-specific and Broad Indexes* (b) *Commodity prices and the Exchange Rate*

Note: Panel (a) display a set of general commodity price indexes together with the country-specific index. In panel (b) the country-specific commodity export price index is plotted along with the nominal exchange rate as an index. In both panels (a) and (b) the indexes are set to 100 in 2005Q1.

Figure 1.4: Exchange Rate Dynamics and Foreign Exchange Intervention.

Note: Nominal Exchange Rate response to a 10 percent commodity export price shock under heavy and light intervention. Heavy and light intervention refers to the 80th and 50th percentile of the corresponding FXI distribution. Measures of Intervention: $FXI_{i,t}^{RA}$ (top panel) and $FXI_{i,t}^{LYS}$ (bottom panel). The nominal exchange rate is defined so that a decrease implies an appreciation. EM7 Countries: Brazil, Chile, Colombia, Guatemala, Mexico, Peru, and Turkey.

Figure 1.5: Exchange Rate Dynamics and Expectations-based CBC.

Note: Cumulative response to a 10 percent commodity export price shock under high and low central bank credibility. High and low central bank credibility refers to the 50th and 80th percentile of the $CRED^{EGap}$ distribution, and to the 80th and 20th percentile of the $CRED^{LLR}$ distribution. EM7 Countries: Brazil, Chile, Colombia, Guatemala, Mexico, Peru, and Turkey.

Figure 1.6: FXI and Expectations-based CBC

Note: Response to a 10 percent Commodity Export Price Shock. Using $FXI_{i,t}^{RA}$ and $CRED_{i,t}^{LLR}$ credibility measure. EM7 Countries: Brazil, Chile, Colombia, Guatemala, Mexico, Peru, and Turkey. The 1st and 2nd columns report the dynamics of the endogenous variables under heavy FXI; the 1st column considers the case of high CBC, while the second column considers the case of low CBC. Similarly, the 4th and 5th columns report the response of the economy under light FXI; the 4th column reports the dynamics under high CBC, while the 5th column reports the dynamics under low CBC. The 3rd and 6th columns report the corresponding differences.

Figure 1.7: Exchange Rate Dynamics: FXI and Expectations-based CBC.

Note: Dynamic response to a 10 percent commodity export price shock under heavy and light foreign exchange intervention, combined with high and low central bank credibility. Heavy and light intervention refers to the 80th and 50th percentile of the corresponding FXI distribution. High and low central bank credibility refers to the 50th and 80th percentile of the $CRED^{EGap}$ distribution, and to the 80th and 20th percentile of the $CRED^{LLR}$ distribution. The nominal exchange rate is defined so that a decrease implies an appreciation. EM7 Countries: Brazil, Chile, Colombia, Guatemala, Mexico, Peru, and Turkey.

Figure 1.8: Exchange Rate Dynamics: FXI and Expectations-based CBC

Note: Response to a positive 10 percent Commodity Export Price Shock. Using $FXI_{i,t}^{RA}$ and $CRED_{i,t}^{EGap}$ credibility measure. EM7 Countries: Brazil, Chile, Colombia, Guatemala, Mexico, Peru, and Turkey.

Figure 1.9: Exchange Rate Dynamics and Foreign Exchange Intervention, EM13.

Note: Nominal Exchange Rate response to a 10 percent commodity export price shock under heavy and light intervention. Heavy and light intervention refers to the 80th and 50th percentile of the corresponding FXI distribution. Measures of Intervention: $FXI_{i,t}^{RA}$ (top panel) and $FXI_{i,t}^{LYS}$ (bottom panel). The nominal exchange rate is defined so that a decrease implies an appreciation. EM13 Countries: Brazil, Chile, Colombia, Guatemala, Hungary, Indonesia, Mexico, Peru, Philippines, Poland, Romania, Thailand, and Turkey.

Figure 1.10: Exchange Rate Dynamics and Observed-inflation-based CBC, EM7.

Note: Cumulative response to a 10 percent commodity export price shock under high and low central bank credibility, using the CBC measures based on realized inflation. High and low central bank credibility refers to the 50th and 80th percentile of the $CRED^{YoY}$ and the $CRED^{1Q}$ distributions. EM7 Countries: Brazil, Chile, Colombia, Guatemala, Mexico, Peru, and Turkey.

Figure 1.11: Exchange Rate Dynamics and Observed-inflation-based CBC, EM13.

Note: Cumulative response to a 10 percent commodity export price shock under high and low central bank credibility, using the CBC measures based on realized inflation. High and low central bank credibility refers to the 50th and 80th percentile of the $CRED^{YoY}$ and the $CRED^{1Q}$ distributions. EM13 Countries: Brazil, Chile, Colombia, Guatemala, Hungary, Indonesia, Mexico, Peru, Philippines, Poland, Romania, Thailand, and Turkey.

Figure 1.12: FXI and Central Bank Credibility, EM13

Note: Response to a 10 percent Commodity Export Price Shock. Using $FXI_{i,t}^{LYS}$ and $CRED_{i,t}^{YoY}$ credibility measure. EM13 Countries: Brazil, Chile, Colombia, Guatemala, Hungary, Indonesia, Mexico, Peru, Philippines, Poland, Romania, Thailand, and Turkey. The 1st and 2nd columns report the dynamics of the endogenous variables under heavy FXI; the 1st column considers the case of high CBC, while the second column considers the case of low CBC. Similarly, the 4th and 5th columns report the response of the economy under light FXI; the 4th column reports the dynamics under high CBC, while the 5th column reports the dynamics under low CBC. The 3rd and 6th columns report the corresponding differences.

CHAPTER 2

EXCHANGE RATE DETERMINATION UNDER ALTERNATIVE INFLATION TARGETS: THE ROLE OF TRADE COSTS

2.1 Introduction

An important branch of the international macroeconomics literature is concerned with the cross-border spillover effects of shocks and their implications for exchange rate determination under inflation targeting (IT). However, shocks to international trade costs and their effects on exchange rate dynamics under the IT regime are largely ignored in this literature.¹ In general, trade costs are a source of frictions in international transactions that may add short-run volatility to the exchange rate via their effects on the terms of trade and inflation, and, therefore, via their interaction with interest rate rules.² Understanding these effects is more relevant than ever since governments around the world have taken a protectionist stance that could lead to an increase in international trade costs.³ Already these trade costs are not negligible: [Anderson and Van Wincoop \(2004\)](#) estimate that for a representative

¹International trade costs can be broadly defined as transportation costs, tariffs, and other policy barriers.

²Although in this paper I emphasize the role of inflation-targeting in the transmission mechanism of trade costs shocks (which one may interpret as terms-of-trade shocks) to the volatility of the exchange rate, other work has found that terms-of-trade shocks can be important even without regard to interest rates rules. For instance, in the context of a real business cycle model, [Mendoza \(1995\)](#) finds that terms-of-trade shocks account for 45 to 60 percent of the observed variability of exchange rates.

³Even before that, in the aftermath of the recent global collapse of international trade, protectionist and murky trade barriers were erected as governments went into crisis-fighting mode ([Baldwin and Evenett, 2011](#)).

rich country, international trade costs amount to a 74% ad-valorem tax equivalent.⁴ Increases in these costs could pose a challenge for IT central banks.

Under IT, increases in international trade costs could feed directly into import prices, increase inflation, and trigger monetary policy reactions, which could have consequences for the exchange rate and the terms of trade. Crucially, these consequences may vary with the magnitude of the inflation rate targeted by the central bank.⁵ Controlling for the prevailing inflation target is important since, as [Ascari and Sbordone \(2014\)](#) have shown in a closed economy model, higher inflation targets are associated with a more volatile and unstable economy, and they can induce a stronger monetary policy response to inflation deviations from target. However, the interaction between trade costs shocks and IT has not been taken into account in the literature and a number of questions remain unanswered. First, what are the implications of shocks to international trade costs for the determination of the nominal exchange rate and the terms of trade under IT, and how do these effects differ under different inflation targets? Second, are the consequences of these shocks different when the shock affects only one economy or the entire world? Third, how do the dynamics of the real exchange rate under trade costs shocks differ from the corresponding dynamics under other shocks typically studied in the literature (e.g. monetary policy shocks)?

⁴[Novy \(2013\)](#) also reports important bilateral trade costs between the US and its trading partners. He finds that trade costs in the year 2000, expressed as a tariff equivalent, were 25% for Canada, and 33% for Mexico. Further, he finds that trade costs are considerably higher for Japan and the UK at over 60%.

⁵There is heterogeneity in the inflation target across countries, and in fact, some countries may even be considering raising their targets. Since the crisis, some economists have recently argued that Central Banks could raise their inflation targets (say, from 2% to 4% in the case of the Federal Reserve) so that monetary policy can have more room for action in the context of deflationary shocks. See [Blanchard et al. \(2010\)](#) and [Ball \(2013\)](#).

This paper seeks to answer these questions. In particular, I study the effects of international trade costs shocks on exchange rate determination under IT. Further, I investigate how these effects differ when the inflation rate targeted by the central bank is positive rather than zero, as the literature usually assumes. To do so I develop a two-country dynamic stochastic general equilibrium (DSGE) model of the New Keynesian (NK) type. I augment the model with international trade costs, and I assume a positive inflation rate in the steady state.⁶

Accounting for trend inflation is empirically relevant and methodologically important.⁷ As [Ascari and Sbordone \(2014\)](#) point out, price stability in central banks is usually associated with a moderate rate of trend inflation. However, NK DSGE models usually assume that the central bank targets a zero inflation rate in its monetary policy rule.⁸ [Ascari and Sbordone \(2014\)](#) study trend inflation in a closed economy model and find that trend inflation affects the dynamics of the economy because it alters the coefficients of the New Keynesian Phillips Curve (NKPC). In particular, in the presence of positive steady state inflation, firms put less weight on current economic conditions and put more weight on future expected output and inflation deviations from target. This implies that the real interest rate differs with different inflation targets, for any given increase in the nominal interest rate. In an open economy, this has implications for the magnitude of interest rate differentials, and therefore not only for how much the exchange rate and the terms of trade react

⁶As [Engel \(2013\)](#) points out, most variants of the open-economy NK models have not focused on the implications of the models for exchange rate dynamics. This current work seeks to close this gap.

⁷The terms trend inflation and steady state inflation are used interchangeable throughout this paper.

⁸This is usually done because the optimal long-run inflation target in many specifications of the NK model is zero ([Goodfriend and King 2001](#), and [Woodford 2003](#)), but also because of analytical convenience.

upon a shock, but also for their respective rates of appreciation or depreciation back to their steady states. The exact behavior of the nominal and real exchange rates, and of the terms of trade will depend on the nature of the shock.

The implications of the model are tested via a standard calibration of the model's parameters. On the first question above, I find that, under IT, a trade costs shock received by the Home economy induces a permanent depreciation of the nominal exchange rate. This result is in line with the study by [Benigno and Benigno \(2008\)](#). They investigate exchange rate dynamics under different interest rate rules and find that in a floating exchange rate regime, under producer currency pricing (PCP), the nominal exchange rate will be non-stationary. This implies that even a stationary real shock can have persistent effects on the nominal exchange rate, which is in line with the results. Further, I find that this permanent depreciation is larger when the inflation rate targeted by the central bank is higher. Additionally, I find that following the shock and the initial appreciation, the nominal exchange rate depreciates faster under higher inflation targets. A faster depreciation implies a larger movement in the exchange rate in a given period, which can lead to more volatility. The literature that studies the relationship between inflation targeting and exchange rates has shown that inflation targeting economies have lower exchange rate volatility (See [Rose \(2007\)](#), and [Gonçalves and Salles \(2008\)](#)). However, this line of research does not take into account the different inflation rates that the central bank may target, and the work done on the macroeconomic implications of different inflation targets has typically focused on closed economy models.⁹ Accordingly, the

⁹Examples include [Ascari and Ropele \(2007\)](#), [Bakhshi et al. \(2007\)](#), and [Ascari and Sbordone \(2014\)](#).

result suggests that, all else equal, higher inflation targets could be associated with higher exchange rate volatility following a shock to international trade costs.¹⁰

On the second question, I find that the exchange rate dynamics depend on whether the trade costs shock hits both economies or only one. On the one hand, if the trade costs shock is received by both economies, then, in a symmetric world, the shock will induce symmetric policy reactions, thereby not having consequences for the nominal exchange rate or the real exchange rate. Nevertheless, the terms of trade depreciate in both countries exclusively due to the trade costs shocks. However, if the world is not perfectly symmetric and say the Foreign economy is more open than the Home economy, then following a symmetric trade costs shock the nominal exchange rate will experience a permanent appreciation, and this appreciation will be larger in magnitude when the inflation target is higher. On the other hand, if the trade costs shock is received only by, say, the Home economy, then the first result above holds and the trade costs shock induces a permanent depreciation of the nominal exchange rate.

On the third question, I find that the real exchange rate exhibits more persistence in its adjustment path given a trade costs shock than given a monetary policy shock. This result is connected to the broader literature that studies persistent deviations of the real exchange rate from purchasing power parity (i.e. the PPP puzzle). On the one hand, the results are in line with [Obstfeld and Rogoff \(2000\)](#), and more recently the work by [Atkeson and Burstein \(2011\)](#), who introduce trade costs to account for the slow convergence of real exchange rates. However, in the latter case the deviations from relative PPP arise as a result of the assumption of pricing-to-market. I don't need this assumption in the model for the real exchange rate to exhibit a high degree of persistence under trade costs shocks. Further, this line

¹⁰Importantly, this result also holds under monetary policy shocks.

of research typically studies the role of trade costs in explaining the PPP puzzle abstracting from a monetary policy framework, while I am particularly interested in understanding the role of trade costs under IT. On the other hand, the results are connected to the literature that studies real exchange rate persistence under interest rate rules. This line of research emphasizes the role of monetary policy shocks. For instance, [Benigno \(2004\)](#), shows that when monetary policy exhibits inertia, then “the real exchange rate exhibits persistence because, through the interest rate differential, its adjustment is also smoothed over time.”¹¹ Not only do I show that a trade costs shock induces more persistence in the real exchange rate than a monetary policy shock, I also show that this persistence is larger when the inflation target is higher.

The structure of the rest of the paper is the following: Section [2.2](#) presents the model, Section [2.3](#) highlights a few key equations to trace the transmission mechanism of a shock to international trade costs, Section [2.4](#) simulates the model and discusses its implications, and Section [3.5](#) concludes.

2.2 Model

The world consists of two economies: the Home and Foreign economies. There are three sets of agents: individuals, firms, and central bank policy makers. Individuals maximize their intertemporal lifetime expected utility function consisting of utility obtained from consuming domestic (home) goods and foreign (imported) goods, together with disutility from supplying labor. The production of goods requires labor input combined with technology. The model employs a Calvo price-setting

¹¹Inertia in the interest rate rule implies that the adjustment of the nominal interest rate toward its target is smoothed over time.

process (Calvo, 1983), in which firms are able to change their prices only with some probability, independent of other firms and the time elapsed since the last adjustment. Firms behave as monopolistic competitors. In all these respects, the model I build in this paper follows Monacelli (2001), but departs from it in two respects.¹² First, imported final goods into both the Home and Foreign economies are subject to country-specific international trade costs. These costs are accounted for in the price paid by consumers in the country importing the good just as in Obstfeld and Rogoff (2001). Second, while Monacelli (2001), and most of the literature using New Keynesian models for monetary policy analysis, approximate their model around a zero inflation steady state, the steady state of the model is assumed to exhibit a positive inflation rate á la Ascari (2004) and Ascari and Sbordone (2014).

A word on notation: Subscripts H and F stand for Home and Foreign-produced, respectively. Superscript $*$ stands for the variables of the Foreign economy. Lower case letters denote log variables. For a generic variable B_t , let $\hat{b}_t = \log(B_t/\bar{B})$. That is, hatted variables stand for log deviations from steady states. Capital letters with a bar on top and without a time subscript denote steady-state values.

Since the model is symmetric (except for the country-specific trade costs) I will mainly focus on the equations of the Home economy unless the discussion requires the introduction of the Foreign equations for clarity. It is understood that for every Home equation discussed there exists a Foreign economy equivalent.

¹²Alternatively, the model can be thought of as a two-country version of the model developed in Gali and Monacelli (2005).

2.2.1 Individuals

The representative individual in the Home country, has the following intertemporal lifetime utility function

$$E_t \left[\sum_{k=0}^{\infty} \beta^k \{U(C_{t+k}) - V(N_{t+k})\} \right] \quad (2.2.1)$$

where $U(C_t)$ is the utility out of consuming a composite index of C_t , $V(N_t)$ is the disutility out of working N_t hours, and $0 < \beta < 1$ is a discount factor. The composite consumption index C_t is defined by

$$C_t = \frac{1}{(1-\gamma)^{(1-\gamma)\gamma}} (C_{H,t})^{1-\gamma} (C_{F,t})^\gamma \quad (2.2.2)$$

where $C_{H,t}$ and $C_{F,t}$ are Home consumption of home and foreign (i.e. imported) goods, respectively, and γ is the share of domestic consumption allocated to imported goods. In this sense, γ is a measure of openness. The consumption sub-index is defined by

$$C_{H,t} = \left[\int_0^1 C_{H,t}(j)^{(\theta-1)/\theta} dj \right]^{\theta/(\theta-1)} \quad \text{and} \quad C_{F,t} = \left[\int_0^1 C_{F,t}(j)^{(\theta-1)/\theta} dj \right]^{\theta/(\theta-1)} \quad (2.2.3)$$

where $C_{H,t}(j)$ and $C_{F,t}(j)$ represent domestic consumption of home and foreign good j , respectively, and $\theta > 1$ is the price elasticity of demand faced by each monopolist.

The individual household constraint in the Home economy is given by

$$\int_0^1 [P_{H,t}(j)C_{H,t}(j) + P_{F,t}(j)C_{F,t}(j)]dj + E_t[F_{t,t+1}B_{t+1}] = W_t N_t + B_t + TR_t \quad (2.2.4)$$

where $F_{t,t+1}$ is the stochastic discount factor, B_{t+1} is the nominal payoff in period $t+1$ of the portfolio held at the end of period t , W_t is the nominal wage, and TR_t is the lump sum transfers/taxes. I assume complete international asset markets.

Optimal consumption allocation

The representative individual in the Home economy chooses optimal levels of consumption of each home and foreign-made good j . Optimal allocation of any given amount of expenditures across each good j yields the following demand functions

$$C_{H,t}(j) = \left(\frac{P_{H,t}(j)}{P_{H,t}} \right)^{-\theta} C_{H,t} \quad \text{and} \quad C_{F,t}(j) = \left(\frac{P_{F,t}(j)}{P_{F,t}} \right)^{-\theta} C_{F,t} \quad (2.2.5)$$

where $P_{H,t}(j)$ is the Home price of Home-produced good j , $P_{F,t}(j)$ is the Home price of Foreign-produced good j . Further, $P_{H,t}$ is the price index of Home-consumed Home-made goods, and $P_{F,t}$ is the price index of Home-consumed Foreign-made (imported) goods.¹³ These are defined as

$$P_{H,t} = \left(\int_0^1 [P_{H,t}(j)]^{1-\theta} dj \right)^{1/(1-\theta)} \quad \text{and} \quad P_{F,t} = \left(\int_0^1 [P_{F,t}(j)]^{1-\theta} dj \right)^{1/(1-\theta)} \quad (2.2.6)$$

Further, conditional on the optimal behavior described above I have that

$$P_{H,t}C_{H,t} = \int_0^1 P_{H,t}(j)C_{H,t}(j)dj \quad \text{and} \quad P_{F,t}C_{F,t} = \int_0^1 P_{F,t}(j)C_{F,t}(j)dj \quad (2.2.7)$$

That is, Home consumption expenditures can be written as the product of the Home price index times the Home quantity index.

The individual maximizes eq. (2.2.2) for any given level of expenditures. Optimal allocation across domestic and imported goods yields the following demand functions for the Home economy

$$C_{H,t} = \frac{(1-\gamma)P_t C_t}{P_{H,t}} \quad \text{and} \quad C_{F,t} = \frac{\gamma P_t C_t}{P_{F,t}} \quad (2.2.8)$$

Where P_t is Home CPI, and is defined as

$$P_t = (P_{H,t})^{1-\gamma} (P_{F,t})^\gamma \quad (2.2.9)$$

¹³Note that since, in the Home economy, consumers are not faced with trade costs, and since they pay for domestically produced goods with domestic currency, then home consumers face source prices when buying domestically produced goods, while they face destination prices when buying foreign goods.

Optimal intertemporal and intratemporal choices

Conditional on optimal behavior I can write $P_{H,t}C_{H,t} + P_{F,t}C_{F,t} = P_tC_t$. This means I can write eq. (2.2.4), i.e. the budget constraint, as

$$P_tC_t + E_t[F_{t,t+1}B_{t+1}] = W_tN_t + B_t + TR_t \quad (2.2.10)$$

The representative Home agent's problem is to choose paths for consumption, portfolio, and the labor supply. Therefore, the representative consumer in the Home economy maximizes her expected utility equation (2.2.1) subject to the budget constraint equation (2.2.10).

Labor supply decision: I assume log-utility of consumption and linear disutility from labor.¹⁴ That is, I assume $U(C_t) = \log C_t$ and $V(N_t) = N_t$.¹⁵ Therefore, the intratemporal problem yields

$$\frac{W_t}{P_t} = C_t \quad (2.2.11)$$

¹⁴I assume a logarithmic utility function for tractability. This functional form for the utility function is commonly used in economic studies. See for instance [Bowen et al. \(2014\)](#), [Azzimonti \(2011\)](#), [Song et al. \(2012\)](#), and [He and Krishnamurthy \(2013\)](#). As it's mentioned in [Bowen et al. \(2014\)](#), if one were to use a more general constant relative risk aversion (CRRA) utility function in which the elasticity of intertemporal substitution is not unity, the results would be qualitatively the same as the results I obtain here by assuming a logarithmic utility function.

¹⁵I assume an implied inverse Frisch elasticity of labor supply of zero in order to obtain the analytical derivations in the paper. If one assumes nonlinear disutility from labor, the dynamic response to shocks would also be affected by the dynamics of prices dispersion (which will be derived below). This would increase the persistence of macroeconomic variables. See [Ascari and Sbordone \(2014\)](#) for a discussion. Nevertheless, the qualitative results of the paper would not change.

Intertemporal optimality: Given the assumption of complete asset markets¹⁶, the intertemporal optimality condition yields the following¹⁷

$$F_{t,t+1} = \beta \left(\frac{C_t}{C_{t+1}} \right) \left(\frac{P_t}{P_{t+1}} \right) \quad (2.2.12)$$

which is satisfied for all states of nature at t and $t + 1$.

I can take conditional expectations of the above and get a conventional Euler equation

$$F_t = \beta E_t \left[\frac{C_t P_t}{C_{t+1} P_{t+1}} \right] \quad (2.2.13)$$

where $F_t = E_t[F_{t,t+1}]$ is the price of a one-period discount bond paying off one unit of Home currency in every state of the world at time $t + 1$. Equivalently, express the Euler equation as

$$\frac{1}{I_t} = \beta E_t \left[\frac{C_t P_t}{C_{t+1} P_{t+1}} \right] \quad (2.2.14)$$

where $I_t = 1/E_t[F_{t,t+1}]$ is the gross return on a risk-less one-period discount bond (or equivalently a riskless portfolio) paying 1 unit of Home currency at time $t + 1$. Equation (2.2.14) represents the traditional intertemporal Euler equation for total real consumption.

International risk sharing

The Foreign economy has an intertemporal optimality condition analogous to the one for the Home economy. In particular, this yields

$$F_{t,t+1} = \beta \left(\frac{C_t^*}{C_{t+1}^*} \right) \left(\frac{P_t^*}{P_{t+1}^*} \right) \left(\frac{\Xi_t}{\Xi_{t+1}} \right) \quad (2.2.15)$$

¹⁶Cole and Obstfeld (1991) show that under Cobb-Douglas-isoelastic preferences (which I assume in this paper), asset trade is redundant in the sense that the allocation reached without asset trade cannot be Pareto-improved by introducing asset markets and making lump-sum transfers. However, assuming complete international asset markets provides a direct vehicle for reaching the expression for the uncovered interest rates parity derived below.

¹⁷For details on this see the discussion on Gali and Monacelli (2005)

Where Ξ_t is the nominal exchange rate, defined as the price of foreign currency in terms of home currency. Setting (2.2.12) and (2.2.15) equal to each other, and after iterating I get

$$C_t = \tilde{c} C_t^* Q_t \quad (2.2.16)$$

where

$$Q_t = \frac{\Xi_t P_t^*}{P_t} \quad (2.2.17)$$

is the real exchange rate, and where $\tilde{c} = \frac{C_0 P_0}{C_0^* \Xi_0 P_0^*}$ is a constant which will generally depend on initial conditions regarding relative net asset positions. Assuming symmetric initial conditions (i.e. zero net foreign asset holdings and an ex-ante identical environment) implies that I can set $\tilde{c} = 1$.

2.2.2 Trade Costs

Iceberg trade costs

I assume that each imported final good j into the home (foreign) economy is subject to asymmetric, i.e. country-specific, international iceberg trade costs τ_t (resp. τ_t^*). So for every unit of foreign (home) good shipped abroad, only a fraction $1 - \tau_t$ (resp. $1 - \tau_t^*$) arrives at the home (foreign) shore. Further, I assume that these costs are the same across goods, i.e. they are not j -dependent. Let $T_t = \frac{1}{1 - \tau_t}$ and $T_t^* = \frac{1}{1 - \tau_t^*}$. Then, in order to purchase one unit of good j from abroad, a home (foreign) consumer effectively needs to pay for T_t (resp. T_t^*) units of the foreign (home) good. That is, assuming producer currency pricing (PCP), the destination prices of imported goods into the Home and Foreign economy are, respectively

$$P_{F,t}(j) = \Xi_t P_{F,t}^*(j) T_t \quad \text{and} \quad P_{H,t}^*(j) = (1/\Xi_t) P_{H,t}(j) T_t^* \quad (2.2.18)$$

That is, the home currency price of an imported foreign variety j is an increasing function of the nominal exchange rate, of the price of the good denominated in foreign currency, and of gross international trade costs. Equivalently, the foreign currency price of an imported home variety j is a decreasing function of the nominal exchange rate (given its definition as the price of foreign currency in terms of domestic currency), and an increasing function of the price of the good denominated in home currency, and of gross international trade costs.

Since the trade costs are not good-specific I can use the definition of the price index of Home-consumed Foreign-made goods, $P_{F,t}$, and of the price index of Foreign-consumed Home-made goods, $P_{H,t}^*$, on Equation (2.2.18) to express these indexes in terms the exchange rate, source prices, and trade costs as

$$P_{F,t} = \Xi_t P_{F,t}^* T_t \quad \text{and} \quad P_{H,t}^* = (1/\Xi_t) P_{H,t} T_t^* \quad (2.2.19)$$

It is assumed that these trade costs evolve according the the following AR(1) process

$$\tau_t = \rho_\tau \tau_{t-1} + \varepsilon_t^\tau \quad \text{and} \quad \tau_t^* = \rho_{\tau^*} \tau_{t-1}^* + \varepsilon_t^{\tau^*} \quad (2.2.20)$$

where $\tau_t = \log T_t$ and $\tau_t^* = \log T_t^*$.

Terms of trade and trade costs

The terms of trade for the Home and Foreign economy, S_t and S_t^* , respectively, are defined as the relative price of imports to exports

$$S_t = \frac{P_{F,t}}{P_{H,t}} \quad \text{and} \quad S_t^* = \frac{P_{H,t}^*}{P_{F,t}^*} \quad (2.2.21)$$

Accordingly, if the terms of trade increase they experience a depreciation. Using eq. (2.2.19) I can rewrite eq. (2.2.21) as

$$S_t = \frac{\Xi_t P_{F,t}^* T_t}{P_{H,t}} \quad \text{and} \quad S_t^* = \frac{(1/\Xi_t) P_{H,t} T_t^*}{P_{F,t}^*} \quad (2.2.22)$$

That is, the terms of trade of both the Home and Foreign economies are an increasing function of gross trade costs. Define domestic inflation as $\pi_{H,t} = \frac{P_{H,t}}{P_{H,t-1}}$, and foreign inflation as $\pi_{F,t}^* = \frac{P_{F,t}^*}{P_{F,t-1}^*}$, and let $\xi_t = \log(\Xi_t)$. Then, log-linearizing the expression for the Home terms of trade in eq. (2.2.22) I get

$$\Delta \hat{s}_t = \hat{\pi}_{F,t}^* - \hat{\pi}_{H,t} + \Delta \hat{\xi}_t + \Delta \hat{\tau}_t \quad (2.2.23)$$

That is, the terms of trade depreciate when foreign inflation increases, when domestic inflation decreases, when the nominal exchange rate depreciates, and when trade costs increase. The terms of trade typically depend on the first three terms on the right-hand-side of eq. (2.2.23). Accounting for trade costs on internationally traded goods, makes the terms of trade depend directly on such costs.

For future reference, I derive a few useful equations. For instance, it's easy to show that the following relationship between the terms of trade in the Home economy and the Foreign economy holds at all times

$$S_t = \frac{T_t T_t^*}{S_t^*} \quad (2.2.24)$$

Log-linearizing Equation (2.2.24) I obtain

$$\hat{s}_t = \hat{\tau}_t + \hat{\tau}_t^* - \hat{s}_t^* \quad (2.2.25)$$

Further, using the definition of the CPI's and the terms of trade in each economy, it can be shown that the following relationships hold:

$$\frac{P_t}{P_{H,t}} = \left(\frac{P_{F,t}}{P_{H,t}} \right)^\gamma = (S_t)^\gamma \quad \text{and} \quad \frac{P_t^*}{P_{F,t}^*} = \left(\frac{P_{H,t}^*}{P_{F,t}^*} \right)^{\gamma^*} = (S_t^*)^{\gamma^*} \quad (2.2.26)$$

Similarly:

$$\frac{P_t}{P_{F,t}} = \left(\frac{P_{H,t}}{P_{F,t}} \right)^{(1-\gamma)} = (S_t)^{(\gamma-1)} \quad \text{and} \quad \frac{P_t^*}{P_{H,t}^*} = \left(\frac{P_{F,t}^*}{P_{H,t}^*} \right)^{(1-\gamma^*)} = (S_t^*)^{(\gamma^*-1)} \quad (2.2.27)$$

Uncovered interest rate parity, terms of trade, and trade costs

As [Gali and Monacelli \(2005\)](#) point out, the assumption of complete international asset markets allows us to obtain a version of the uncovered interest parity condition (UIRP). Indeed, note that under complete markets the equilibrium price (in terms of the Home economy's currency) of a bond which pays one unit of Foreign currency is given by $\Xi_t F_t^* = E_t[F_{t,t+1} \Xi_{t+1}]$, where F_t^* is the price of the bond in terms of Foreign currency. I can combine this Foreign pricing equation with the Home bond pricing equation $F_t = E[F_{t,t+1}]$ to obtain a version of the UIRP:

$$E_t[F_{t,t+1} I_t] = E_t[F_{t,t+1} I_t^* (\Xi_{t+1}/\Xi_t)] \quad (2.2.28)$$

where I_t and I_t^* are the gross return on the risk-free Home and Foreign bond, respectively. Log-linearizing eq. (2.2.28) around the steady state yields

$$\hat{i}_t - \hat{i}_t^* = E_t[\hat{\xi}_{t+1}] - \hat{\xi}_t \quad (2.2.29)$$

Expected changes in the nominal exchange rate depend on nominal interest rate differentials. Now, using the definition of S_t , and of $P_{F,t}$ in terms of source prices, trade costs, and the exchange rate, (and the definition of S_t^* , and of $P_{H,t}^*$ in terms of source prices, trade costs, and the exchange rate) I get that

$$E_t \left[\frac{S_{t+1}}{S_t} \right] = E_t \left[\frac{\Xi_{t+1}}{\Xi_t} \frac{T_{t+1}}{T_t} \frac{\pi_{F,t+1}^*}{\pi_{H,t+1}} \right] \quad E_t \left[\frac{S_{t+1}^*}{S_t^*} \right] = E_t \left[\frac{\Xi_{t+1}}{\Xi_t} \frac{T_{t+1}^*}{T_t^*} \frac{\pi_{H,t+1}}{\pi_{F,t+1}^*} \right] \quad (2.2.30)$$

Log-linearizing (2.2.30) and using (2.2.29) I obtain the following expressions for the terms of trade

$$\hat{s}_t = (\hat{i}_t^* - E_t[\hat{\pi}_{F,t+1}^*]) - (\hat{i}_t - E_t[\hat{\pi}_{H,t+1}]) + E_t[\hat{s}_{t+1} - \Delta \hat{\tau}_{t+1}] \quad (2.2.31)$$

$$\hat{s}_t^* = (\hat{i}_t - E_t[\hat{\pi}_{H,t+1}]) - (\hat{i}_t^* - E_t[\hat{\pi}_{F,t+1}^*]) + E_t[\hat{s}_{t+1}^* - \Delta \hat{\tau}_{t+1}^*] \quad (2.2.32)$$

That is, the terms of trade depend on real interest rate differentials, on an expectation of what the terms of trade will be next period, and on the expected change on the trade costs. Rearranging equation (2.2.31) I can find an expression for the rate of change of the terms of trade in terms of real interest rate differentials and expected changes in trade costs.

$$E_t[\Delta \hat{s}_{t+1}] = E_t[\Delta \hat{\tau}_{t+1}] + (\hat{i}_t - E_t[\hat{\pi}_{H,t+1}]) - (\hat{i}_t^* - E_t[\hat{\pi}_{F,t+1}^*]) \quad (2.2.33)$$

That is, the terms of trade depend on real interest rate differentials, and on expected changes in trade costs. Eq. (2.2.33) says that for a given rate of change of the trade costs, the rate of change of the terms of trade will be larger in magnitude when the interest rate differential is larger. This is crucial, since as I shall see in future sections, higher inflation targets are associated with larger real interest rate differentials, thereby implying a larger depreciation of the terms of trade following a trade costs shock under higher inflation targets.

Alternatively, note that in the symmetric steady state the terms of trade are uniquely pinned down. In particular, I show in Appendix B that $\bar{S} = \bar{T}$ in the steady state. If I combine this fact with the assumption of stationarity in the model's driving forces, then $\lim_{T \rightarrow \infty} E_t[\hat{s}_T] = 0$. Therefore, solving eq. (2.2.31) forward I obtain

$$\hat{s}_t = E_t \left\{ \sum_{k=0}^{\infty} \left[(\hat{i}_{t+k}^* - \hat{\pi}_{F,t+k+1}^*) - (\hat{i}_{t+k} - \hat{\pi}_{H,t+k+1}) \right] \right\} + \hat{\tau}_t \quad (2.2.34)$$

That is, the terms of trade are a function of current trade costs, and of current and anticipated real interest rate differentials.

CPI inflation and trade costs

Let π_t be Home CPI inflation, and π_t^* be Foreign CPI Inflation

$$\pi_t = \frac{P_t}{P_{t-1}} \quad \pi_t^* = \frac{P_t^*}{P_{t-1}^*} \quad (2.2.35)$$

Using the definitions of P_t and P_t^* , and eqs. (2.2.26) and (2.2.27) I obtain

$$\pi_t = \pi_{H,t} \left(\frac{S_t}{S_{t-1}} \right)^\gamma \quad \pi_t^* = \pi_{F,t}^* \left(\frac{S_t^*}{S_{t-1}^*} \right)^{\gamma^*} \quad (2.2.36)$$

Log-linearizing eq. (2.2.36) I get

$$\hat{\pi}_t = \hat{\pi}_{H,t} + \gamma \Delta \hat{s}_t \quad \hat{\pi}_t^* = \hat{\pi}_{F,t}^* + \gamma^* \Delta \hat{s}_t^* \quad (2.2.37)$$

That is, CPI inflation increases if domestic inflation increases, and if the terms of trade depreciate. In the latter, the increase in CPI inflation occurs up to the level of openness of the economy. Now, using Equation (2.2.23) and its Foreign equivalent on the expressions in eq. (2.2.37) I get

$$\hat{\pi}_t = (1 - \gamma) \hat{\pi}_{H,t} + \gamma [\Delta \hat{\tau}_t + \hat{\pi}_{F,t}^* + \Delta \xi_t] \quad (2.2.38)$$

and

$$\hat{\pi}_t^* = (1 - \gamma^*) \hat{\pi}_{F,t}^* + \gamma^* [\Delta \hat{\tau}_t^* + \hat{\pi}_{H,t} - \Delta \xi_t] \quad (2.2.39)$$

That is, CPI inflation is a weighted average of local inflation and imported inflation from abroad. The contribution of each source of inflation towards CPI inflation is proportional to the share of consumption allocated to locally-produced and imported goods, respectively. Furthermore, a depreciation of the nominal exchange rate (from the point of view of Home) is passed through to CPI inflation up to the level of openness of the economy. This nominal exchange rate increase (an increase in the value of Foreign currency) decreases Foreign CPI inflation. Finally, an increase in trade costs feeds into CPI inflation up to the level of openness of the economy. Under CPI inflation targeting this would induce monetary policy responses whose ramifications (I will show) vary with the inflation target, thereby having consequences for exchange rate determination according to the UIRP condition in eq. (2.2.29).

Eqs. (2.2.38) and (2.2.39) imply that I can consider symmetric and asymmetric trade costs shocks under symmetric or asymmetric parametrizations of the openness parameter. For instance, I can simulate a symmetric trade costs shock when both economies are equally open, i.e. when $\gamma = \gamma^*$, and both τ_t and τ_t^* increase by the same magnitude for some periods. I can also consider a symmetric trade costs shock when one economy is more open than the other, say $\gamma < \gamma^*$. And I can consider an increase in trade costs for the Home economy only (i.e. an asymmetric trade costs shock), when both economies are equally open. I will in fact do this in section 2.4.

Real exchange rate and trade costs

Using (2.2.19), (2.2.26), and (2.2.24) I can express the real exchange rate as

$$Q_t = (S_t)^{(1-\gamma-\gamma^*)} \frac{(T_t^*)^{\gamma^*}}{(T_t)^{(1-\gamma^*)}} \quad (2.2.40)$$

Log-linearizing Equation (2.2.40) I get

$$\hat{q}_t = (1 - \gamma - \gamma^*)\hat{s}_t + \gamma^*\hat{\tau}_t^* - (1 - \gamma^*)\hat{\tau}_t \quad (2.2.41)$$

Taking first differences of Equation (2.2.41) and using Equation (2.2.23) I obtain

$$\Delta\hat{q}_t = (1 - \gamma - \gamma^*) [\hat{\pi}_{F,t}^* - \hat{\pi}_{H,t} + \Delta\xi_t] - \gamma\Delta\hat{\tau}_t + \gamma^*\Delta\hat{\tau}_t^* \quad (2.2.42)$$

Eq. (2.2.42) shows that, all else equal, following a temporary trade costs shock the changes in the real exchange rate will be small each period if the shock is persistent, i.e. if $\Delta\hat{\tau}_t$ is small each period. That is, high persistence in a trade costs shock translates into high persistence for the real exchange rate.

2.2.3 Resource Constraint

Market clearing with trade costs

Market clearing of a domestically-produced variety j requires that the quantity produced of each good matches the quantity demanded. Therefore I must have

$$Y_t(j) = C_{H,t}(j) + C_{H,t}^*(j)T_t^* \quad (2.2.43)$$

where $Y_t(j)$ is the domestic output of good j , and where the presence of T_t^* reflects the fact that domestic firms exporting to Foreign need to ship out T_t^* times the amount $C_{H,t}^*(j)$ of good j ultimately consumed by individuals in the Foreign economy. An analogous argument applies to Foreign firms. Now, using the optimal choices for $C_{H,t}(j)$ and $C_{H,t}^*(j)$, eq. (2.2.43) becomes

$$Y_t(j) = \left[\frac{P_{H,t}(j)}{P_{H,t}} \right]^{-\theta} C_{H,t}^A \quad (2.2.44)$$

where

$$C_{H,t}^A = C_{H,t} + C_{H,t}^* T_t^* \quad (2.2.45)$$

That is, $C_{H,t}^A$ is the aggregate world demand for the goods produced in the Home economy. Now, using the optimal choices of $C_{H,t}$ and $C_{H,t}^*$ eq. (2.2.44) becomes

$$Y_t(j) = \left[\frac{P_{H,t}(j)}{P_{H,t}} \right]^{-\theta} \left[\frac{(1-\gamma)P_t C_t}{P_{H,t}} + \frac{\gamma^* P_t^* C_t^*}{P_{H,t}^*} T_t^* \right] \quad (2.2.46)$$

Now, define aggregate output in the Home economy as

$$Y_t = \left(\int_0^1 Y_t(j)^{\frac{\theta-1}{\theta}} dj \right)^{\frac{\theta}{\theta-1}} \quad (2.2.47)$$

I can use eq. (2.2.44) in eq. (2.2.47) to easily show that $Y_t = C_{H,t}^A$. That is, aggregate domestic output equals aggregate world demand for Home-produced goods. This means that I can write

$$Y_t = \frac{(1-\gamma)P_t C_t}{P_{H,t}} + \frac{\gamma^* P_t^* C_t^*}{P_{H,t}^*} T_t^* \quad (2.2.48)$$

and also that

$$Y_t(j) = \left[\frac{P_{H,t}(j)}{P_{H,t}} \right]^{-\theta} Y_t \quad (2.2.49)$$

Starting from eq. (2.2.48), I can factor out the terms C_t , and $P_t/P_{H,t}$, use the risk-sharing condition, the definition of Q_t , and the fact that $\Xi_t P_{H,t}^* = T_t^* P_{H,t}$ to obtain the following expression relating aggregate domestic output to domestic consumption and price levels:

$$Y_t = C_t \left(\frac{P_t}{P_{H,t}} \right) \mu \quad (2.2.50)$$

where $\mu_t = [1 - \gamma + \gamma^*]$. Using the fact that $P_t/P_{H,t} = S_t^\gamma$ eq. (2.2.50) becomes

$$Y_t = C_t S_t^\gamma \mu \quad (2.2.51)$$

Eq. (2.2.50) (or equivalently eq. (2.2.51)) describes the resource constraint in an open economy. Log-linearizing (2.2.51) I get

$$\widehat{y}_t = \widehat{c}_t + \gamma \widehat{s}_t \quad (2.2.52)$$

2.2.4 Firms

Production

I assume a continuum of monopolistically competitive firms indexed by $j \in [0, 1]$.

Home firms have the following constant returns to scale production function:

$$Y_t(j) = Z_t N_t(j) \quad (2.2.53)$$

where Z_t is the total factor productivity shifter for Home firms, and is equal across goods and firms. In particular, these technology shocks are given by the following AR(1) process

$$z_t = \rho_z z_{t-1} + \varepsilon_t^z \quad (2.2.54)$$

where $z_t = \log Z_t$. From the cost minimization problem of a firm who receives an employment subsidy of ω for every unit of labor employed I get the following standard real marginal cost expression

$$MC_t = (1 - \omega) \frac{W_t}{P_{H,t} Z_t} \quad (2.2.55)$$

That is, real marginal costs increase when real wages increase, and decrease when productivity increases.

Calvo pricing

The model employs a Calvo price-setting process, in which producers are able to change their prices only with some probability $(1 - \alpha)$, independently of other producers and the time elapsed since the last adjustment. It is assumed that producers behave as monopolistic competitors. Each Home producer faces the following demand function:

$$Y_t(j) = \left[\frac{\tilde{P}_{H,t}(j)}{P_{H,t}} \right]^{-\theta} Y_t \quad (2.2.56)$$

A producer that is able to set a new price at time t chooses a price $\tilde{P}_{H,t}$ in order to maximize the current market value of the profits generated while that price remains effective. That is, the reoptimizing firm chooses $\tilde{P}_{H,t}$ to solve the following problem:

$$\max_{\tilde{P}_{H,t}} E_t \left[\sum_{k=0}^{\infty} \alpha^k F_{t,t+k} Y_{t+k}(j) \left(\tilde{P}_{H,t} - MC_{t+k}^n \right) \right] \quad (2.2.57)$$

where α is the probability that producers maintain the same price of the previous period. The problem of the producers is to maximize equation (2.2.57) subject to the demand constraint (2.2.56). The first order necessary condition of the firm for this maximization is:

$$E_t \left[\sum_{k=0}^{\infty} \alpha^k F_{t,t+k} Y_{t+k}(j) \left(\tilde{P}_{H,t} - \mathcal{M} MC_{t+k}^n \right) \right] = 0 \quad (2.2.58)$$

where $\mathcal{M} = \frac{\theta}{\theta-1}$. Using the demand function (2.2.56), the resource constraint (2.2.50), and the definition of the stochastic discount factor $F_{t,t+k} = \beta^k C_t P_t / C_{t+k} P_{t+k}$

I obtain

$$\sum_{k=0}^{\infty} (\alpha\beta)^k E_t \left[(\Pi_{H,t,t+k})^{\theta-1} \tilde{P}_{H,t}^{-\theta} P_{H,t} \left(\frac{\tilde{P}_{H,t}}{P_{H,t}} - \mathcal{M} \Pi_{H,t,t+k} MC_{t+k} \right) \right] = 0 \quad (2.2.59)$$

where $\Pi_{H,t,t+k}$ is the cumulative gross inflation rate from time t to time $t+k$, that is

$$\Pi_{H,t,t+k} = \begin{cases} 1 & \text{for } k = 0; \\ \left(\frac{P_{H,t+1}}{P_{H,t}} \right) \times \cdots \times \left(\frac{P_{H,t+k}}{P_{H,t+k-1}} \right) & \text{for } k = 1, 2, \dots \end{cases}$$

and $MC_{t+k} = \frac{MC_{t+k}^n}{P_{H,t+k}}$ is the real marginal cost.

Optimal reset price and aggregate price level dynamics

Solving for the relative optimal price $X_t = \frac{\tilde{P}_{H,t}}{P_{H,t}}$ I get

$$X_t = \frac{\tilde{P}_{H,t}}{P_{H,t}} = \mathcal{M} \frac{\sum_{k=0}^{\infty} (\alpha\beta)^k E_t [\Pi_{H,t,t+k}^{\theta} MC_{t+k}]}{\sum_{k=0}^{\infty} (\alpha\beta)^k E_t [\Pi_{H,t,t+k}^{\theta-1}]} = \mathcal{M} \frac{\psi_t}{\phi_t} \quad (2.2.60)$$

Where ψ_t and ϕ_t are introduced as auxiliary variables. It can be shown that I can express ψ_t and ϕ_t recursively as

$$\psi_t = MC_t + (\alpha\beta) E_t [\pi_{H,t+1}^{\theta} \psi_{t+1}] \quad (2.2.61)$$

and

$$\phi_t = 1 + (\alpha\beta) E_t [\pi_{H,t+1}^{\theta-1} \phi_{t+1}] \quad (2.2.62)$$

Note that in the limiting case of no price rigidities ($\alpha = 0$), eq. (2.2.60) collapses to

$$X_t = \mathcal{M} MC_t = \frac{\theta}{\theta-1} MC_t \quad (2.2.63)$$

as in the standard model. Therefore, I can still interpret $\mathcal{M} = \frac{\theta}{\theta-1}$ as the optimal markup in the absence of constraints on the frequency of price adjustment, i.e. in

the flexible price economy. Which is why, as [Galí \(2015\)](#) points out, $\mathcal{M}$ is referred to as the “desired”, “natural”, or “frictionless” markup.

The optimal relative price in eq. (2.2.60) is a standard result: firms set prices in a forward-looking fashion given that prices are sticky ($\alpha > 0$). Therefore, firms choose an optimal price that corresponds to the desired markup over a weighted average of their current and expected nominal marginal costs. The difference between a model that assumes that the central bank targets a zero inflation rate, and one that assumes that the central bank targets a positive inflation rate as I do in this paper, are the weights given to future marginal costs at the time the linear approximation is computed.

As [Ascari and Sbordone \(2014\)](#) noted regarding eq. (2.2.60) in their closed economy model: future expected inflation enters both the numerator and the denominator, effectively weighing future marginal costs. I see here that in an open economy this remains true. If these forward-looking firms expect higher inflation rates in the future, they will assign more weight to future expected nominal marginal costs. In this sense, firms become more forward-looking, assigning more weight to future than to current economic conditions.

Note that eq. (2.2.60) in the steady state is

$$X = \frac{\tilde{P}_H}{P_H} = \mathcal{M} \frac{\sum_{k=0}^{\infty} (\alpha \beta \pi_H^\theta)^k MC}{\sum_{k=0}^{\infty} (\alpha \beta \pi_H^{\theta-1})^k} = \mathcal{M} \frac{\psi}{\phi} \quad (2.2.64)$$

That is, convergence of ϕ and ψ in eq. (2.2.64) is conditional on

$$\alpha \beta \pi_H^\theta < 1 \quad \text{and} \quad \alpha \beta \pi_H^{\theta-1} < 1 \quad (2.2.65)$$

respectively. For a standard calibration of parameters of $\alpha = 0.75$, and $\beta = 0.99$, this implies that the trend inflation rate cannot exceed 12.6 and 14.1 percent annually.¹⁸

The aggregate price level dynamics are expressed as

$$1 = \alpha \pi_{H,t}^{\theta-1} + (1 - \alpha) X_t^{1-\theta} \quad (2.2.66)$$

Equivalently, this can be expressed as

$$X_t = \frac{\tilde{P}_{H,t}}{P_{H,t}} = \left[\frac{1 - \alpha \pi_{H,t}^{\theta-1}}{1 - \alpha} \right]^{\frac{1}{1-\theta}} \quad (2.2.67)$$

Log-linearization of the Calvo pricing equations

As has been mentioned before, most models are approximated around a zero-inflation steady state. However, in this paper, I am interested in controlling for different inflation targets. Accordingly, I log-linearize eqs. (2.2.60), (2.2.61), (2.2.62), and (2.2.67) around a positive steady state inflation rate, $\pi_H > 0$, and obtain

$$\hat{x}_t = \hat{\psi}_t - \hat{\phi}_t \quad (2.2.68)$$

$$\hat{\psi}_t = (1 - \alpha \beta \pi_H^\theta) \widehat{mc}_t + (\alpha \beta \pi_H^\theta) \left[\theta E_t[\hat{\pi}_{H,t+1}] + E_t[\hat{\psi}_{t+1}] \right] \quad (2.2.69)$$

$$\hat{\phi}_t = (\alpha \beta \pi_H^{\theta-1}) \left[(\theta - 1) E_t[\hat{\pi}_{H,t+1}] + E_t[\hat{\phi}_{t+1}] \right] \quad (2.2.70)$$

$$\hat{x}_t = \frac{\alpha \pi_H^{\theta-1}}{(1 - \alpha \pi_H^{\theta-1})} \hat{\pi}_{H,t} \quad (2.2.71)$$

New Keynesian Phillips Curve and marginal costs

I can combine eqs. (2.2.68), (2.2.69), (2.2.70), and (2.2.71) to find the New Keynesian Phillips Curve (NKPC) in terms of marginal costs and positive steady state

¹⁸This nuance has already been noticed by King and Wolman (1996), Ascari (2004), and Ascari and Sbordone (2014)

inflation consisting of two equations, namely:

$$\hat{\pi}_{H,t} = \eta_1 \widehat{mc}_t + \eta_2 E_t[\hat{\pi}_{H,t+1}] + \eta_3 E_t[\hat{\psi}_{t+1}] \quad (2.2.72)$$

$$\hat{\psi}_t = (1 - \alpha\beta\pi_H^\theta) \widehat{mc}_t + (\alpha\beta\pi_H^\theta) \left[\theta E_t[\hat{\pi}_{H,t+1}] + E_t[\hat{\psi}_{t+1}] \right] \quad (2.2.73)$$

where η_1 , η_2 , and η_3 are coefficients defined as

$$\begin{aligned} \eta_1 &= \frac{(1 - \alpha\beta\pi_H^\theta)(1 - \alpha\pi_H^{\theta-1})}{\alpha\pi_H^{\theta-1}} \\ \eta_2 &= \beta [1 + \theta(\pi_H - 1)(1 - \alpha\pi_H^{\theta-1})] \\ \eta_3 &= \beta(\pi_H - 1)(1 - \alpha\pi_H^{\theta-1}) \end{aligned} \quad (2.2.74)$$

As eqs. (2.2.72) and (2.2.73) show, positive steady state inflation matters for inflation dynamics because it alters the coefficients of the NKPC. Figure (2.1) plots the values taken by the weights η_1 , η_2 , and η_3 , for a standard parametrization of the Calvo parameter, the discount factor, and the elasticity of substitution, against different values of annualized trend inflation.¹⁹ As is evident from the figure, the weight, η_1 , that forward-looking firms assign to current marginal costs is a decreasing function of annualized trend inflation. That is, when the inflation target is higher, the weight that firms place on current economic conditions is lower. While the opposite is true of the weights, η_2 and η_3 , assigned to future economic conditions. That is, as the inflation target increases, firms place a higher weight on future expected inflation and future expected marginal costs.

Note that when the target for the inflation rate is zero, i.e. in a zero inflation steady state, the steady state gross trend inflation is equal to 1, that is $\pi_H = 1$. Therefore, in the zero inflation steady state case: η_3 goes to zero, making the auxiliary variable ψ_t disappear from the NKPC, $\eta_2 = \beta$, and $\eta_1 = \frac{(1-\alpha\beta)(1-\alpha)}{\alpha}$.

¹⁹That is, for $\alpha = 0.75$, $\beta = 0.99$, and $\theta = 9$

Implying that the NKPC derived above collapses to its usual expression (when the model is log-linearized around a zero steady state inflation):

$$\hat{\pi}_{H,t} = \beta E_t[\hat{\pi}_{H,t+1}] + \frac{(1 - \alpha\beta)(1 - \alpha)}{\alpha} \widehat{mc}_t \quad (2.2.75)$$

These coefficients correspond to the the first point in the x-axis in figure (2.1), i.e. for a zero annualized inflation rate.

2.2.5 Equilibrium

The dynamic IS equation

In order to derive the IS equation for the Home economy I lead equation (2.2.36) by one period and I combine it with the Euler equation (2.2.14) to get

$$\beta E_t \left[I_t \frac{C_t}{C_{t+1}} \frac{(S_t)^\gamma}{(S_{t+1})^\gamma} \frac{1}{\pi_{H,t+1}} \right] = 1 \quad (2.2.76)$$

I log-linearize it, and solve for $\widehat{c}_t$ in (2.2.52) (and for $\widehat{c}_{t+1}$ by leading one period). I plug the resulting expression into equation (2.2.76) to get, after some manipulation:

$$\widehat{y}_t = E_t[\widehat{y}_{t+1}] - (\widehat{i}_t - E_t[\widehat{\pi}_{H,t+1}]) \quad (2.2.77)$$

As always, output depends positively on future expected output, and negatively on the real interest rate.

The NKPC in terms of output

Now I derive expressions for the IS curve and the NKPC in terms of output deviations from target. Start with the marginal cost equation (2.2.55), multiply and divide by P_t , use the Labor Supply decision $C_t = W_t/P_t$, the fact that $S_t^\gamma = P_t/P_{H,t}$, and the market clearing condition (2.2.51), to obtain

$$MC_t = \frac{(1 - \omega)}{\mu} \frac{Y_t}{Z_t} \quad (2.2.78)$$

I log-linearize this expression to I obtain

$$\widehat{mc}_t = \hat{y}_t - \hat{z}_t \quad (2.2.79)$$

Therefore, the NKPC can be expressed in terms of log-deviations of output and technology for their steady states as:

$$\hat{\pi}_{H,t} = \eta_1(\hat{y}_t - \hat{z}_t) + \eta_2 E_t[\hat{\pi}_{H,t+1}] + \eta_3 E_t[\hat{\psi}_{t+1}] \quad (2.2.80)$$

with η_1 , η_2 , and η_3 as defined above, and where

$$\hat{\psi}_t = (1 - \alpha\beta\pi_H^\theta)(\hat{y}_t - \hat{z}_t) + (\alpha\beta\pi_H^\theta) \left[\theta E_t[\hat{\pi}_{H,t+1}] + E_t[\hat{\psi}_{t+1}] \right] \quad (2.2.81)$$

The Home-Foreign output relationship

I now find an expression to relate the level of Home output to the level of Foreign output. To do so I use Equations (2.2.40), (2.2.16), (2.2.51) and its symmetric Foreign version, and (2.2.24). That is, I use the relationship between Q_t , S_t , and T_t , the risk-sharing condition, the market clearing conditions for the Home and Foreign economies, and the relationship between Home and Foreign TOT's. I obtain:

$$Y_t = Y_t^* \frac{S_t}{T_t} \frac{\mu}{\mu^*} \quad (2.2.82)$$

Log-linearizing (2.2.82) to obtain

$$\hat{y}_t = \hat{y}_t^* + \hat{s}_t - \hat{t}_t \quad (2.2.83)$$

The IS equation, the NKPC, and the output gap

As listed in Appendix B, the steady state level of output $\bar{Y}$ depends on steady state inflation π_H . Appendix B shows that in the steady state all inflation rates are the same. That is,

$$\bar{\pi} = \pi_H^* = \pi_H = \pi_F = \pi_F^* = \bar{\pi}^* \quad (2.2.84)$$

Accordingly, I can say that the steady state level of output $\bar{Y}$ depends on steady state inflation $\pi_H = \bar{\pi}$. Let $\bar{Y}(\bar{\pi})$ denote the steady state level of output for a given level of trend inflation $\bar{\pi}$. Then, in general, $\hat{y}_t$ is

$$\hat{y}_t = \log Y_t - \bar{Y}(\bar{\pi}) \quad (2.2.85)$$

Define the output gap, $y_{gap,t}$, as the log-deviation of current output from the output that would arise in a flexible-price environment, namely the natural level of output Y_t^n . Indeed, the $y_{gap,t}$ is a measure of the nominal distortion implied by sticky prices.

$$y_{gap,t} = \log Y_t - \log Y_t^n \quad (2.2.86)$$

Appendix B shows that the output gap can be expressed in terms of output and the technology process as

$$y_{gap,t} = \hat{y}_t - \hat{z}_t + \tilde{y} \quad (2.2.87)$$

where $\tilde{y} = \log \bar{Y}(\bar{\pi}) - \log \bar{Y}_{flex}$, and $\bar{Y}_{flex}$ is the steady state output under flexible prices, which happens to coincide with the steady state output under zero steady state inflation (ZISS), i.e. $\bar{Y}_{flex} = \bar{Y}(1)$. As [Ascari and Sbordone \(2014\)](#) point out, $\tilde{y}$ is the deviation of the level of output associated with steady state inflation $\bar{\pi}$ from the level of long-run output under flexible prices (or when steady state inflation is zero). I can find an expression for $\tilde{y}$ in terms of the fundamental parameters as:

$$\tilde{y} = \log \left(\frac{1 - \alpha\beta\pi_H^\theta}{1 - \alpha\beta\pi_H^{\theta-1}} \right) + \frac{1}{1 - \theta} \log \left(\frac{1 - \alpha\pi_H^{\theta-1}}{1 - \alpha} \right) \quad (2.2.88)$$

which clearly equals 0 when $\alpha = 0$, i.e. under flexible prices.

All of this implies that I can express the Home NKPC in terms of the output gap as follows

$$\hat{\pi}_{H,t} = \eta_1(y_{gap,t} - \tilde{y}) + \eta_2 E_t[\hat{\pi}_{H,t+1}] + \eta_3 E_t[\hat{\psi}_{t+1}] \quad (2.2.89)$$

$$\hat{\psi}_t = (1 - \alpha\beta\pi_H^\theta)(y_{gap,t} - \tilde{y}) + (\alpha\beta\pi_H^\theta) \left[\theta E_t[\hat{\pi}_{H,t+1}] + E_t[\hat{\psi}_{t+1}] \right] \quad (2.2.90)$$

with η_1 , η_2 , and η_3 defined as before.

IS Curve and the output gap

I can express the IS curve in terms of the output gap. Start with the IS curve and use the fact that $y_{gap,t} = \hat{y}_t - \hat{z}_t + \tilde{y}$, solve for $\hat{y}_t$, lead one period and use into the IS curve.

$$y_{gap,t} = E_t[y_{gap,t+1}] - (\hat{i}_t - E_t[\hat{\pi}_{H,t+1}]) + E_t[\Delta\hat{z}_{t+1}] \quad (\text{IS})$$

2.2.6 Monetary Policy

In order to close the model I specify a rule for the nominal interest rate. As always, I focus on the rule for the Home economy, keeping in mind that there exists a Foreign equivalent. I specify a CPI-based Taylor Rule with smoothing, namely:

$$\hat{i}_t = \rho_i \hat{i}_{t-1} + (1 - \rho_i)(\phi_\pi \hat{\pi}_t + \phi_y \hat{y}_t) + \nu_t \quad (2.2.91)$$

the monetary policy shock is given by the AR(1) process:

$$\nu_t = \rho_\nu \nu_{t-1} + \varepsilon_t^\nu \quad (2.2.92)$$

As usual, the coefficients ϕ_π and ϕ_y are chosen by the monetary authority.

I focus on analyzing the consequences of targeting CPI instead of domestic inflation, even in the face of terms-of-trade shocks (which is not optimal in these models), from a consideration of how monetary policy is conducted in practice. Indeed, the reality is that some inflation-targeting Central Banks react to spikes in consumer price inflation arising from terms-of-trade shocks when they are worried about the degree of anchoring of inflation expectations, and when they think that a

shock that becomes protracted could impact the public's expectations. In this case, policymakers decide to take action in the face of these shocks instead of letting the spike in inflation work its way through. For recent examples of Central Banks in Latin America that engaged in this type of behavior see [IMF \(2018b\)](#). And even if focusing on CPI-inflation is not current practice among Central Banks in advanced economies, some economists have argued that it should be (see for instance [Bullard 2011](#)).

2.3 The mechanism of a trade costs shock

The full linearized model can be found in [Appendix B](#). However, in this section I would like to highlight some equations in order to trace the mechanism of a trade costs shock. In particular I highlight the Home IS curve, the NKPC, an expression for the terms of trade in terms of real interest rate differentials and trade costs, an expression that relates the nominal exchange rate and the trade costs to the terms of trade, the UIRP condition, an expression for CPI inflation, the CPI-based Taylor Rule, and an expression for the real exchange rate.

$$\hat{y}_t = E_t[\hat{y}_{t+1}] - (\hat{i}_t - E_t[\hat{\pi}_{H,t+1}]) \quad (2.3.1)$$

$$\hat{\pi}_{H,t} = \eta_1(\hat{y}_t - \hat{z}_t) + \eta_2 E_t[\hat{\pi}_{H,t+1}] + \eta_3 E_t[\hat{\psi}_{t+1}] \quad (2.3.2)$$

$$\hat{\psi}_t = (1 - \alpha\beta\pi_H^\theta)(\hat{y}_t - \hat{z}_t) + (\alpha\beta\pi_H^\theta) \left[\theta E_t[\hat{\pi}_{H,t+1}] + E_t[\hat{\psi}_{t+1}] \right] \quad (2.3.3)$$

$$\hat{s}_t = (\hat{i}_t^* - E_t[\hat{\pi}_{F,t+1}^*]) - (\hat{i}_t - E_t[\hat{\pi}_{H,t+1}]) + E_t[\hat{s}_{t+1} - \Delta\hat{\tau}_{t+1}] \quad (2.3.4)$$

$$\Delta\hat{s}_t = \Delta\hat{\tau}_t + \hat{\pi}_{F,t}^* - \hat{\pi}_{H,t} + \Delta\xi_t \quad (2.3.5)$$

$$\hat{i}_t - \hat{i}_t^* = E_t[\hat{\xi}_{t+1}] - \hat{\xi}_t \quad (2.3.6)$$

$$\hat{\pi}_t = \hat{\pi}_{H,t} + \gamma\Delta\hat{s}_t \quad (2.3.7)$$

$$\hat{i}_t = \rho_i \hat{i}_{t-1} + (1 - \rho_i)(\phi_\pi \hat{\pi}_t + \phi_y \hat{y}_t) + \nu_t \quad (2.3.8)$$

$$\Delta \hat{q}_t = (1 - \gamma - \gamma^*) [\hat{\pi}_{F,t}^* - \hat{\pi}_{H,t} + \Delta \xi_t] - \gamma \Delta \hat{\tau}_t + \gamma^* \Delta \hat{\tau}_t^* \quad (2.3.9)$$

Consider a temporary increase in international trade costs only for the Home economy. That is, suppose τ_t increases temporarily, while $\tau_t^* = 0$ for all t . According to eq. (2.3.5) the Home terms of trade immediately depreciate, feeding directly into CPI inflation as per eq. (2.3.7). The CPI inflation increase induces a monetary policy response according to the Taylor Rule in eq. (2.3.8). That is, the central bank increases the nominal interest rate in order to bring CPI inflation back to target. This induces a short-run appreciation of the nominal exchange rate. This appreciation partly offsets the effect of the trade costs increase in the CPI inflation. However, the trade costs increase dominates the offsetting effect of the nominal exchange rate appreciation, which is why the CPI inflation increases in the first place.

Since the shock has been received only by the Home economy the Foreign central bank will not react unless there are spillovers. In this case, the spillovers to the Foreign economy occur via the nominal exchange rate decrease. This induces an increase in foreign CPI inflation. Since the change in the nominal exchange rate is lower in magnitude than the initial trade costs increase in the Home economy, the increase in foreign CPI inflation is not as large as the increase in home CPI inflation. This induces the Foreign central bank to increase nominal interest rates by a lower amount than the required increase in the Home economy in order to bring CPI inflation back to target. This nominal interest rate differential implies that, after the initial appreciation, the nominal exchange rate will depreciate according the UIRP condition in eq. (2.3.6). All this implies that following a trade costs shock, the nominal exchange rate will depreciate faster (after its initial appreciation) when

the interest rate differentials are higher. As I will discuss in the simulations section below, this will occur when the inflation target is higher.

Furthermore, following the shock, the real exchange rate experiences an initial appreciation just like the nominal exchange rate, according to eq. (2.3.9). Afterwards, the changes in the real exchange rate will track the changes in the nominal exchange rate, inflation differentials, and the changes in the trade costs. This implies that each period the changes in the real exchange rate will be small if the shock is persistent, i.e. if $\Delta\hat{\tau}_t$ is small each period. That is, high persistence in a trade costs shock translates into high persistence for the real exchange rate.

2.4 Simulations

In this section I conduct simulation exercises to test the theoretical implications of the model. Appendix B spells out the full linearized model.²⁰ I employ a standard calibration of the model's parameters in order to interpret each period as a quarter. Appendix B contains a full list of the underlying parameters and its assumed values. I perform the simulations in Dynare.

2.4.1 Trade Costs Shocks under different inflation targets

Figure (2.2) shows the dynamic response of the nominal and real exchange rates, and of other key variables when only the Home economy receives a 1 percent trade costs shocks, and both monetary policy authorities use CPI-based Taylor Rules.²¹

²⁰For the interested reader, Appendix B spells out the equations of the full non-linear model.

²¹The interested reader is directed to figures (B.1) and (B.2) in Appendix B for the dynamic response of variables other than those found in figure (2.2). These figures show the impulse response functions of most of the endogenous variables of both the Home and

A trade cost shock received only by the Home economy feeds directly into the CPI via a depreciation of the terms of trade, as eq. (2.2.23) shows. This triggers the response of the monetary policy authority who raises the nominal interest rate in order to bring CPI inflation back to target. Recall that positive steady state inflation enters the coefficients of the NKPC, as shown in eqs. (2.2.89) and (2.2.90), making firms more forward looking. That is, under higher inflation targets firms put a lower weight on current economic conditions and a higher weight on future expected economic conditions. This implies that following a shock, firms will not place as much weight on the current induced output drop as they would in an economy that targets a zero inflation rate. Therefore, the domestic inflation rate decreases less when the inflation target is higher. This makes the real interest rate increase by a higher amount when the inflation target is higher. That is, the larger the steady state inflation, the larger the increase in real interest rates for a given increase in nominal interest rates.

Even though the trade costs shock is received by the Home economy, there are spillovers to the Foreign economy via the terms of trade and the nominal exchange rate. Upon impact the nominal exchange rate appreciates (from the point of view of the Home economy). This feeds directly into Foreign CPI as can be seen in eq. (2.2.39). This increase in Foreign CPI occurs proportionally to the increase of the nominal exchange rate up to the Foreign openness parameter γ^* . Since the trade costs shock occurs only in the Home economy, i.e. $\Delta\hat{\tau}^* = 0$ for all t in eq. (2.2.39), and since the change in the nominal exchange rate is lower in magnitude than the initial trade costs increase in the Home economy, the increase in foreign CPI inflation is not as large as the increase in home CPI inflation. This induces a

Foreign economies, respectively, following this shock. I included only some of these IRFs in Figure (2.2) due to their relevance to the present discussion.

monetary policy response in the Foreign economy (to bring CPI inflation back to target) that is lower in magnitude than the response in the Home economy. The asymmetric consequences of the shock result in real interest rate differentials. These differentials arise since the Foreign real interest rate does not increase as much as the Home real interest rate, and remains well below the Home levels in each period following the shock.

The nominal and real exchange rates

Following the initial appreciation, the nominal exchange rate depreciates to a new value in the long run, as Figure (2.3) shows. This result is in line with the study by Benigno and Benigno (2008), who investigate exchange rate dynamics under different interest rate rules. They find that in a floating exchange rate regime, under PCP (as in the model), the nominal exchange rate will be non-stationary. This implies that even a stationary real shock can have persistent effects on the nominal exchange rate, which is in line with the results. Importantly, I find that this permanent depreciation is larger when the inflation rate targeted by the central bank is higher.

The depreciation of the nominal exchange rate brings CPI inflation back to the steady state, and this occurs faster when the economy exhibits high trend inflation. In the context of a closed economy model, Ascari and Sbordone (2014) mention that trend inflation tends to increase the persistence of macroeconomic variables. In an open economy setup, this is generally the case, except in the case of the nominal exchange rate. The nominal exchange rate appreciates much faster in the high trend inflation case, following a shock to international trade costs. According to the UIRP condition, the changes in the nominal exchange rate will be larger if the interest rate differential is larger. Since the nominal interest rate increases by

more in the high trend inflation case it immediately follows that the rate of change of the nominal exchange rate will be faster in every quarter following the shock. That is, the nominal exchange rate depreciates faster in each quarter when there is high trend inflation. This in turn makes the CPI get back to steady state faster in the high trend inflation case. The top panel in Fig. (2.4) plots the change in the nominal exchange rate in every quarter following the shock. This figure makes clear that the nominal exchange rate depreciates faster (i.e. experiences larger changes each quarter) under higher inflation targets, and this is due to the larger interest rate differentials under higher inflation targets. A faster depreciation implies a larger movement in the exchange rate in a given period, which can lead to more volatility. Accordingly, the result suggests that, all else equal, higher inflation targets could be associated with higher exchange rate volatility following a shock to international trade costs.

The top panel of Figure (2.6) plots the path of the real exchange rate. The slow adjustment of the real exchange rate following the shock is evident. This is due to the direct influence of the trade costs on the adjustment of the real exchange rate. As eq. (2.2.42) shows, the rate of change of the real exchange rate depends on the rate of change of the trade costs up to the openness parameter. A trade costs shock that exhibits high persistence will decrease slowly, thereby depreciating the real exchange rate at a slow pace. Further, I find that this slower adjustment is even slower under higher inflation targets. The top panel of Figure (2.7) shows that for the first two years after a trade costs shock, the depreciation of the real exchange rate occurs at a slower pace when the inflation target is higher.

The terms of trade

Given the real interest rate differentials, the asymmetric trade costs shock induces the Home terms of trade to not depreciate one-to-one with the increase in trade costs. Indeed, note in eq. (2.2.34) that the terms of trade can be expressed in terms of the contemporaneous trade costs, and all future expected real interest rate differentials. If the real interest rate is higher in the Home economy at all times, this will have the effect of appreciating the terms of trade. On the other hand, a contemporaneous positive deviation of trade costs from its steady state, i.e. a trade costs shock, has the effect of depreciating the terms of trade. Recall that the trade costs shock is 1 percent on impact, and that this increases the CPI inflation by less than 1 percent (given that $\gamma < 1$, and given the partial offsetting effect of the nominal exchange rate appreciation). Further, given the smoothing nature of the nominal interest rate, this induces a nominal interest rate increase of much less than 1 percent on impact. From eq. (2.2.34) then, it's clear that the depreciation-inducing trade costs term, τ_t , will always dominate the appreciation-inducing real interest rate differential. Accordingly, I observe that the terms of trade remain depreciated (with respect to its initial value) at all times after the initial shock.

Note that not only do the Home terms of trade depreciate, which is natural given the increase in trade costs, but they actually depreciate less when the inflation target is higher. The reason becomes clear after inspecting eq. (2.2.34) again: the determination of the terms of trade depends both on trade costs and on current and expected future real interest rate differentials. As it was mentioned above, on the one hand, an increase in trade costs induces a depreciation of the terms of trade. On the other hand, a real interest rate differential in which the Home real interest rate is larger than the Foreign real interest rate, induces an appreciation of the Home terms of trade. In general, the relative size of both effects will determine whether the

terms of trade appreciate or depreciate relative to the steady state in each period. Now, being an exogenous variable, the trade costs shock does not depend on the inflation target. However, the size of the real interest rate differential does depend on the inflation target that prevails in the economy. Under higher inflation targets I have shown that the real interest rate response is more pronounced, thereby pulling the Home terms of trade more towards an appreciation. However, the effect of the increase in trade costs dominates the effect of the real interest rate differentials in each period. Nonetheless, the effect of the real interest rate differentials is not negligible and is in fact larger under higher inflation targets. It immediately follows that the Home terms of trade depreciate less under higher inflation targets.

2.4.2 Symmetric Trade Costs Shock under different inflation targets

In this section I analyze the response of the economy to a 1 percent symmetric trade costs shock when the Taylor Rule of both economies reacts to CPI inflation. When the model is calibrated symmetrically there are no interest rate differentials since both monetary policy authorities react symmetrically to the shock. Accordingly, the nominal exchange rate remains unchanged. Further, since the magnitude of the shock is the same on both economies, the effect of changes in the trade costs in the Home and Foreign economies will cancel each other out in every period, as can be seen in eq. (2.2.42). Now, since there are no interest rate differentials, the terms of trade depreciate one-to-one with the increase in trade costs according to eq. (2.2.34). Accordingly, following the initial depreciation, the terms of trade appreciate at the rate that the trade costs shock vanishes. This implies that if the

trade costs shocks exhibits high persistence, then the depreciation of the terms of trade will occur slowly.

However, in a world that is not perfectly symmetric, even a symmetric trade costs shock affecting both economies will have consequences for the nominal and real exchange rates. Now I analyze the consequence of the same shock, but with the assumption that the Foreign economy is more open than the Home economy. In particular, I now assume that $\gamma^* = 0.5$, while maintaining all other parameters at their same values. The middle panel of figure (2.3) plots the path of the nominal exchange rate following the shock. As can be seen in this figure, following an initial depreciation, the nominal exchange rate experiences a permanent appreciation, and this appreciation is larger in magnitude when the inflation target is higher. The middle panel of figure (2.4) shows that the nominal exchange rate exhibits larger changes each period on its way back to the new steady state under higher inflation targets. This is due to the interest rate differentials induced by the higher exposure of the Foreign economy to external shocks. The higher nominal interest rate increase in the Foreign economy, relative to the increase in the Home economy can be seen in figure (2.5).

2.4.3 Monetary policy shock under different inflation targets

For comparison, I give the Home economy a monetary policy shock of 25 basis points (1 percent annualized). The bottom panel of figure (2.3) plots the path of the nominal exchange rate under different inflation targets. Following the monetary policy shock, the nominal exchange rate appreciates and then converges to a negative value. That is, in the long-run, the nominal exchange rate experiences a

permanent appreciation, while under the trade costs shock studied above, the nominal exchange rate experiences a permanent depreciation after its initial appreciation. Interestingly, the permanent appreciation is much lower in magnitude under higher inflation targets. In the bottom panel of figure (2.4) I plot the changes in the nominal exchange rate following the shock, and I can observe that, as in other cases, the changes experienced by the nominal exchange rate are larger in magnitude every quarter under higher inflation targets. However, they converge to their respective new steady states at around the same time. As the figure suggests, converge towards the new steady state, however, occurs much faster under monetary policy shocks than under international trade costs shocks.

The monetary policy shock also induces persistence in the adjustment path of the real exchange rate towards its initial value. However, the real exchange rate converges much more quickly to its steady state following a monetary policy shock than following a trade costs shock. That is, the real exchange rate exhibits more persistence, i.e. a slower pace of adjustment back to its equilibrium value, under trade costs shocks than under monetary policy shocks.

2.5 Conclusion

This paper studied the implications of international trade costs shocks on exchange rate determination under the inflation targeting regime. Understanding the consequences of these shocks is important given the protectionist rhetoric coming from important countries around the world. If this rhetoric translates into policies that raise the costs of international trade, then monetary policymakers need to understand the implications of these shocks for important variables like the exchange rate, especially in the context of inflation targeting.

To study these shocks, I developed a two-country DSGE model of the New Keynesian type in which the monetary policy authority targets CPI inflation. I assumed that internationally traded goods are subject to iceberg trade costs and, in order to properly account for the implications of having different inflation targets, I assumed a positive inflation rate in the steady state of the model.

I found that a trade costs shock received by the Home economy leads to a permanent depreciation of the nominal exchange rate, and that this permanent depreciation is larger in magnitude under higher inflation targets. Further, I found that the nominal exchange rate exhibits changes of larger magnitude in each period following the shock under higher inflation targets. This suggests a higher nominal exchange rate volatility associated with higher inflation targets. I also found that when the entire world is subject to the same increase in trade costs, a country that allocates a higher consumption share to imported goods will experience a permanent nominal exchange rate appreciation in the long run. This implies that an inflation targeting country that is more open than its trading partners is more exposed to shocks to international trade costs with long-run consequences for the nominal value of its currency under the floating regime. Finally, I found that following a shock to international trade costs, the real exchange rate exhibits a slow pace of adjustment towards its equilibrium value. The implied persistence of the real exchange rate is higher under trade costs shocks than under monetary policy shocks.

Certainly, many things remain to be done from an empirical and theoretical perspective, and the results suggest some testable predictions. First, the finding that suggests that higher inflation targets are associated with higher exchange rate volatility could be confronted with the data. The literature finds that IT is usually associated with lower exchange rate volatility, but this literature does not control for the different inflation rates that a central bank may target as I do here. Second,

an interesting implication of the results is related to the exchange rate pass-through (ERPT) that an IT economy may face. The ERPT literature shows that larger changes in the nominal exchange rate are associated with higher pass-through measures. Consequently, the finding suggests that economies that have higher inflation targets could face higher ERPT. An empirical study of this theoretical implication is warranted, and could have important policy implications. Third, this paper assumed that only final consumption goods were subject to international trade costs. However, an important portion of international trade takes the form of trade in intermediate goods. The model in this paper can be augmented to be able to study the pricing decisions of firms that face trade costs, and their implications for the exchange rate under IT. In this case, even domestic inflation targeting could have consequences for the exchange rate. Fourth, the implications for exchange rate dynamics under IT when capital mobility is subject to international trade costs remains to be understood. Finally, this paper focused on two large countries (or two large economic blocks). The question remains whether these results differ for a small open economy. These are some possible directions for future research.

Figure 2.1: NKPC Coefficients vs Annualized Trend Inflation

Note: NKPC weights on current and future expected economic conditions.

Figure 2.2: Impulse Response Functions: Trade Costs Shock in the Home Economy

— $\pi_H = 0\%$ - - - $\pi_H = 2\%$ ····· $\pi_H = 4\%$

Note: Dynamic responses to a 1 percent trade costs shock received by the Home economy under different inflation targets.

Figure 2.3: Impulse Response Functions: Nominal Exchange Rate

Note: Dynamic response of the nominal exchange rate to a 1 percent trade costs shock (top and middle panels), and to a monetary policy shock of 25 basis points (bottom panel) under different inflation targets.

Figure 2.4: Quarterly Changes of the Nominal Exchange Rate

Note: Quarterly changes of the nominal exchange rate following a 1 percent trade costs shock (top and middle panels), and a monetary policy shock of 25 basis points (bottom panel) under different inflation targets.

Figure 2.5: Impulse Response Functions: Trade Costs Shock to both Home and Foreign

— $\pi_H = 0\%$ - - - $\pi_H = 2\%$ ···· $\pi_H = 4\%$
 Note: Dynamic response to a 1 percent symmetric trade costs shock under different inflation targets, when the Foreign economy is more open than the Home economy.

Figure 2.6: Impulse Response Functions: Real Exchange Rate

Note: Dynamic response of the real exchange rate to a 1 percent trade costs shock (top panel), and to a monetary policy shock of 25 basis points (bottom panel) under different inflation targets.

Figure 2.7: Quarterly Changes of the Real Exchange Rate

Note: Quarterly changes of the real exchange rate following a 1 percent trade costs shock (top panel), and a monetary policy shock of 25 basis points (bottom panel) under different inflation targets.

CHAPTER 3

EXCHANGE RATE PASS-THROUGH INTO MICRO PRICES

3.1 Introduction

The appropriate formulation and implementation of monetary policy under the inflation targeting regime requires a thorough understanding of the extent to which external shocks can affect consumer prices. In a small open economy, for instance, policymakers need to be aware of the extent to which changes in the nominal exchange rate may induce changes in the prices of imported products — i.e. the exchange rate pass-through.¹ This is particularly the case in emerging market economies since: (i) these economies tend to be subject to large nominal exchange rate shocks (Nordstrom et al., 2009), (ii) the literature has found that these economies tend to exhibit higher degrees of exchange rate pass-through (Burstein and Gopinath, 2014), and (iii) monetary policy authorities in these economies don't have a long inflation targeting track record, which puts pressure on them to try to curb what may be even temporary spikes in consumer prices (Nordstrom et al., 2009).

When an exchange rate shock occurs, monetary policymakers have choices to make. On the one hand, under inflation targeting (IT), policymakers can look through the inflation impact of changes in nominal exchange rates, but when exchange rate pass-through (ERPT) is high this impact may undermine the credibility of the IT framework and policymakers might be compelled to take action (IMF,

¹Exchange rate pass-through refers to the possibility that exchange rate changes may induce changes in the domestic-currency price of imported goods and services. Suppose the nominal exchange rate depreciates and an importer pays for an imported product in foreign currency (i.e. the import is invoiced in foreign currency). The importer may now increase the domestic-currency price of the import in order to pass-through the cost increase to consumers. This is one mechanic way in which an exchange rate depreciation leads to an increase in the (domestic-currency) price of imports.

2018b). On the other hand, if ERPT is low there is no trade-off: the nominal exchange rate can facilitate the adjustment and stabilization of the real economy, and policymakers can conduct an independent and countercyclical monetary policy without worrying about consumer price inflation.

With this in mind, it's important to know the level of ERPT. In this chapter, I take a granular approach and introduce a novel data set to the literature in order to study the ERPT into imported agricultural products into Turkey. Turkey is a small open economy which formally adopted inflation targeting in 2006, and has seen its exchange rate wildly fluctuate over the years (see Figure 3.1). This makes the country a good candidate for study given the discussion above.

The data set I introduce has two main advantages over others used in the literature. First, it consists of the daily wholesale prices of imported agricultural commodities into Istanbul, Turkey. To my knowledge, this is one of a few databases available in which the frequency of the observations is daily. One of the main findings in this chapter will be to establish a relationship between the level of ERPT and the storage potential of an agricultural commodity (a concept related to the literature on the economic effects of depreciation of inventories). Having a daily investigation is crucial for establishing this relationship, since at higher levels of aggregation (e.g. monthly or quarterly frequencies) one would miss the fact that some agricultural commodities have a storage potential of only a few days (e.g. raspberries have a storage potential of 1 week). Second, the data source contains the corresponding daily prices for domestically produced agricultural products. This allows me to construct a relevant measure that controls for all other macroeconomic developments in Turkey which may affect the prices of agricultural commodities, thereby allowing me to properly identify the pure effect of nominal exchange rate changes on prices.

The daily wholesale prices are then combined with data on the nominal exchange rate (NER), on the frequency with which the daily import prices change (which I measure over the sample period), and on the storage potential (in weeks). Doing so I confirm a variety of empirical regularities found in the ERPT literature, as well as establishing new facts, especially related to the relationship between ERPT and the storage potential of perishable agricultural commodities. This chapter goes beyond the standard linear investigation of ERPT and considers potential nonlinearities. This is in line with a recent trend in the ERPT which uses nonlinear/threshold models. For instance, in this literature, [Shintani et al. \(2013\)](#) conclude that the low ERPT associated with the 1980s and 1990s is likely due to low inflation. Similarly, [Ben Cheikh and Rault \(2016\)](#) use a logistic smooth transition model for five heavily indebted countries, to show that ERPT tends to be higher when sovereign bond yield spreads exceed a certain threshold; [Cheikh and Louhichi \(2016\)](#) use a threshold model on a set of 63 countries to show that those countries that experience higher degrees of ERPT are also those countries that have higher rates of inflation; and [Donayre and Panovska \(2016\)](#) study Canada and Mexico, and they show, using a threshold vector autoregression, that episodes of larger growth rates of output are associated with higher ERPT. This chapter contributes to this recent literature by considering how ERPT varies when the NER changes, the frequency of price change, and the storage life exceed certain thresholds. Additionally, and as mentioned above, this chapter uses a highly disaggregated data, as opposed to those papers mentioned above, thus avoiding aggregation bias and allowing me to establish new empirical results in the literature.

Using standard empirical methods the chapter findings are in line with existing studies that employ lower frequencies of data. I find evidence for incomplete daily ERPT of about 5%. This result is similar to studies that use good-level data sets

(e.g. see [Aron et al. \(2014\)](#), [Gopinath et al. \(2010\)](#), and [Lott and Einav \(2013\)](#)). However, the magnitude of the coefficients in this chapter are lower when compared to those in studies using more aggregated data (e.g. see [Goldberg and Knetter \(1996\)](#), and [Menon \(1995\)](#)).

Once nonlinearities are considered, as described above, the degree of ERPT doubles to 10% when NER changes are larger than 0.55% daily, when the daily frequency of price change is above 3.12%, and when the storage potential of an agricultural commodity is above 10 weeks. The result that ERPT is higher when NER changes exceed a certain threshold is in line with the findings in [Burstein et al. \(2005\)](#), who show that the magnitude of NER changes may be effective in the determination of ERPT. The finding that the frequency of price changes may affect the degree of ERPT is in line with the findings in [Gopinath and Itskhoki \(2010\)](#), who show a positive relationship between the frequency with which prices change and the magnitude of the ERPT. In particular, and in line with our findings, the authors of that study find that, on average, products with a high frequency of price adjustment have a long-run ERPT that is at least twice as high as that of those goods with low-frequency of adjustment. The final finding of the paper, positively linking the storage potential of an agricultural commodity and the degree of ERPT, is in line with an economic channel in which the seller of a perishable product needs to sell the good as soon as possible, due to its high rate of depreciation. This implies that sellers of more perishable products (those with lower storage potential) will be less inclined to try to pass-through their higher costs to consumers in the event of an exchange rate shock. On the contrary, an importer of commodities with longer shelf lives may pass-through her higher costs simply because she can afford to wait for an optimal price. This channel is in line with the studies of [Kryvtsov and Midrigan](#)

(2012), and [Alessandria et al. \(2013\)](#), who show that the optimal price of a seller decreases as the depreciation rate of its inventories increase.

The rest of the paper is organized as follows: Section 3.2 introduces the data set, Sector 3.3 describes the methodology employed, Section 3.4 presents and discusses the results, and Section 3.5 concludes.

3.2 Data

The data set consists of daily wholesale prices of 52 agricultural products imported into Istanbul, Turkey, from January 2005 until August 2015. The data source was obtained from the web page of the Istanbul Metropolitan Municipality.² Of particular importance for this chapter, the data source distinguishes between imported and domestically-produced agricultural commodities. This works perfectly for the investigation: to control for local macroeconomic effects I construct the daily *domestic* inflation rate using daily wholesale price data for 311 domestically-produced agricultural commodities within Turkey and sold in Istanbul. I construct such domestic inflation rate by calculating the average percentage change in good-level prices, after ignoring the outlier goods, where outlier goods are defined as those that have price changes more than 2 standard deviations away from the average inflation.

This data set is combined with the daily nominal exchange rate between the Turkish Lira and the U.S. dollar. This data was obtained from the web page of The Central Bank of the Republic of Turkey. We use the Lira/U.S. dollar exchange rate given that U.S. dollars are the main currency used for Turkish imports and that most of global trade takes place in U.S. dollars. In particular, [Nazlioglu and Soytaş \(2011\)](#), [Richards et al. \(2012\)](#), and [Schaffnit-Chatterjee et al. \(2010\)](#) show

²The web page of Istanbul Metropolitan Municipality is www.ibb.gov.tr.

that agricultural products are globally traded in U.S. dollars, and [Gopinath \(2015\)](#), show that the majority (60%) of Turkish imports are invoiced in U.S. dollars, while only 3% of them are invoiced in Turkish liras. Given that imports from the U.S. account for only 6% of total Turkish imports, it follows that the U.S. dollar is the main foreign currency used for invoicing Turkish imports, regardless of what country these products come from. Data concerning the storage potential of each agricultural commodity in the sample comes from [Cantwell \(2001\)](#).

3.3 Empirical Methodology

The specification used in this study follows [Campa and Goldberg \(2005\)](#) and [Burstein and Gopinath \(2014\)](#). In particular, to obtain the ERPT measure I estimate:

$$\Delta p_{g,t} = \alpha + \left(\sum_{k=0}^T \beta_k \Delta e_{t-k} \right) + \gamma \pi_t + \delta_g + S_t + \epsilon_t \quad (3.3.1)$$

where $\Delta p_{g,t}$ is the log change of the daily wholesale price of good g , β_k captures the exchange rate pass through of the k th lag of the log NER change, Δe_{t-k} is the k th lag of the log NER change, π_t is the daily domestic inflation rate, δ_g s are good-fixed effects, S_t is a vector of dummies representing seasonality controls, and ϵ_t is the error term.

Lag selection is achieved by using the standard AIC and BIC criteria, together with the significance of the corresponding coefficients. The control variable π_t facilitates the identification of the ERPT coefficient. Since π_t captures the average price of locally produced agricultural commodities, this variable implicitly captures all Turkey-specific macroeconomic characteristics that may have an impact on the prices of these internationally traded agricultural commodities, thereby facilitating the identification of the ERPT coefficient. Good fixed effects, δ_g help control for

good-specific factors that may affect the good-specific prices. Given the daily frequency of our data set, I follow [Al-Ississ \(2010\)](#), [Ali et al. \(2017\)](#), [Boffa et al. \(2014\)](#), and [Boffa et al. \(2014\)](#), and include weekday fixed effects, monthly fixed effects, and Ramadan fixed effects in the vector of time fixed effects S_t . The importance of controlling for these fixed effects can be seen in Figures [3.2](#), [3.3](#), [3.4](#), and [3.5](#), which plot the daily log change of the exchange rate during Ramadan and during non-Ramadan days, and during different weekdays, months, and years, respectively. Similarly, Figures [3.6](#), [3.7](#), [3.8](#), and [3.9](#), plot the daily log change of the prices of the agricultural commodities during Ramadan and during non-Ramadan days, and during different weekdays, months, and years, respectively. As the figures show, the dispersion of the daily log changes depend on what dates are considered, lending support to the use of these fixed effects.

3.3.1 Nonlinearities

We also consider potential nonlinearities in the determination of ERPT. The literature studying nonlinearities in ERPT has made use both of the threshold approach and of the smooth transition framework. In a threshold regression (TR), the transition from one regime to the next is instantaneous in the sense that the nonlinearity kicks in fully and immediately once the transition variable passes its threshold value. While in a smooth transition regression (STR) the transition across extreme regimes is gradual. The choice of one approach over another depends on whether the analysis is at the macro or microeconomic level. At the aggregate level, as [Ben Cheikh and Rault \(2017\)](#) point out, “firms form very diverse opinions about the macroeconomic environment in the importing country; hence, assuming an abrupt transition from one regime to the other is unrealistic.” Any heterogeneity across firms in how they

perceive the state of the importer's macroeconomic conditions may be hidden due to the aggregation. In that case, the nonlinearity in ERPT may be smooth and the estimation needs to be able to capture a potential gradual transition across regimes. However, when the analysis is at the microeconomic level, as it is in the case of this paper, [Ben Cheikh and Rault \(2017\)](#) point out that a single foreign firm has the ability to change prices sharply in response to changes in the macroeconomic condition of the importing country. In this case, a threshold regression approach is more appropriate. Accordingly, I make use of the following threshold regression specification:

$$\Delta p_{g,t} = \alpha + \left(\sum_{k=0}^T \beta_k \Delta e_{t-k} I(q_{g,t} \leq \tau) \right) + \left(\sum_{k=0}^T \beta_k \Delta e_{t-k} I(q_{g,t} > \tau) \right) + \gamma \pi_t + \delta_g + S_t + \epsilon_t \quad (3.3.2)$$

where $q_{g,t}$ is the threshold variable (representing the NER, the frequency of price change or the storage potential of a given product), τ is the corresponding threshold value, $I(q_{g,t} \leq \tau)$ is an indicator function which takes the value of 1 if $q_{g,t} \leq \tau$ and 0 otherwise, and $I(q_{g,t} > \tau)$ is an indicator function taking the value of 1 if $q_{g,t} > \tau$ and 0 otherwise. For any given τ , the coefficients β_k are obtained via ordinary least squares. The question, however, remains on how the threshold value is found. We follow [Chan et al. \(1993\)](#) and [Hansen \(2000\)](#) and estimate the threshold τ by performing a grid search over all possible values of τ such that the residual sum of squares is minimized. In particular, denote $R(\tau)$ the residual sum of squares (RSS) obtained when the value τ is used for the sample split. The estimate for τ is found via least squares by minimizing $R(\tau)$ over all possible values of τ . Denoting this consistent estimator of the threshold by $\hat{\tau}$, I look for:

$$\hat{\tau} = \arg \min_{\tau} R(\tau) \quad (3.3.3)$$

For practical purposes, considering all possible values of τ amounts to considering at most all possible values of the threshold variable $q_{g,t}$ in the sample. Furthermore, following Hansen (1999), since it is desirable to have an adequate amount of observations on either side of the threshold one may eliminate from the search the highest and lowest 15% of the ordered values of $q_{g,t}$ to end up with a range of values, $[\underline{\tau}, \bar{\tau}] = \Gamma$, over which to search. I do this only in the case of the exchange rate, and the frequency of price change thresholds. Without losing significant accuracy I perform the minimization by using a grid search over Γ in the case of the exchange rate and the frequency of price change thresholds. For the storage potential threshold I perform the search for τ over all possible values of the storage potential. Practically, by plotting the RSS, $R(\tau)$, for all values of τ , one can immediately identify which τ minimizes it. This can be seen in Figures 3.10, 3.11, and 3.12. In particular, the threshold values are 0.55% for the exchange rate, 3.12% for the frequency of price change, and 10 days for the storage potential.

3.4 Results

3.4.1 Lag Selection

I first determine the optimal amount of lags of the exchange rate to be used in all other estimations. To achieve this I estimate Equation 3.3.1 considering different lags of the NER up to $T = 8$. The results are shown in Table 3.1. The standard AIC and BIC criteria for lag selection both select $T = 1$ as the optimal amount of lags to be used. However, the corresponding ERPT coefficient is statistically insignificant (see column 2). This insignificance holds whether one considers some or all possible controls (see Table 3.2). Accordingly, I continue the analysis considering only the

contemporaneous ERPT coefficient, that is, considering lags only up to $T = 0$. This is in line with [Lott and Einav \(2013\)](#), who study daily ERPT using data on *eBay* transactions of U.S. imports from Germany. With this in mind, the coefficient β_0 in Equation [3.3.1](#) will be the measure of ERPT in this chapter.

As a baseline, the results of the estimation of Equation [3.3.1](#) presented in Table [3.1](#) and Table [3.2](#) show that the average wholesale price response of an agricultural commodity to a 1 percent depreciation is about 0.05 percent. Equivalently, one could say that given a 100% depreciation, the price of an imported agricultural commodity would increase by about 5%. This evidence is in line with that presented in the literature. In particular, the literature tends to find evidence for incomplete ERPT pass-through (i.e. a less than 1 to 1 relationship between exchange rate changes and price changes). This result is similar to studies that use good-level data sets (e.g. see [Aron et al. \(2014\)](#), [Gopinath et al. \(2010\)](#), and [Lott and Einav \(2013\)](#)), although the magnitude of the coefficients in this chapter are lower when compared to those in studies using more aggregated data (e.g. see [Goldberg and Knetter \(1996\)](#), and [Menon \(1995\)](#)).

3.4.2 ERPT Across Time

I now consider the possibility that ERPT may be higher or lower in certain years in the sample period. Sample selection is a known source of bias in any empirical study, and it may be the case that selecting certain time frames yields a different picture for the average price increase to exchange rate changes. With this in mind, I estimate Equation [3.3.1](#) for each year in the sample. The results are reported in Table [3.3](#). As the results show, 2009, 2010, and 2015 are years in which the ERPT coefficient increased significantly to 0.23, 0.38, and 0.29 percent, respectively.

These magnitudes are more in line with those reported in studies using more highly aggregated data, suggesting that aggregation bias as well as sample selection may play an important role in the magnitudes of ERPT found in empirical work.

Additionally, some of the years in which ERPT was significantly higher were also years in which the exchange rate experienced rapid depreciations, suggesting, along the lines of [Burstein et al. \(2005\)](#), that the size of the NER shock may matter for the degree of ERPT. I investigate this matter in the next subsection.

3.4.3 ERPT and Nonlinearities

I now consider potential nonlinearities by estimating Equation [3.3.2](#), where the threshold values were found by minimizing the residual sum of squares as described in [Chan et al. \(1993\)](#) and [Hansen \(2000\)](#), and as discussed in Section [3.3](#). One further consideration comes from the paper by [Gopinath et al. \(2010\)](#), who suggest that the degree of ERPT may be conditional on actual price changes — i.e. ERPT may be higher when it occurs at a time when prices actually change. To entertain this possibility, I estimate Equation [3.3.2](#) on the entire sample (i.e. considering no restrictions on price changes), and on the sub-sample that includes only those observations in which prices actually change (i.e. considering only nonzero price changes). Accordingly, I present the results for the threshold analysis by distinguishing between all price changes and nonzero price changes.

Tables [3.4](#), [3.6](#), and [3.8](#) present the results using the threshold values for the magnitude of the exchange rate change, for the frequency of price change, and for the storage potential, using all price changes. In turn, Tables [3.5](#), [3.7](#), and [3.9](#) present the results using the threshold values for the same variables, but using only nonzero price changes. Each table consists of four columns. Columns 1 through 3

include some controls and exclude others, while column 4 includes all controls and all fixed effects, and is therefore the baseline for comparison across specifications. For ease of discussion, the exchange rate pass-through coefficients of interest (those in column 4) have been summarized in Table 3.10.

On the one hand, as Table 3.10 shows, when the estimation is achieved considering all price changes, there is evidence of *incomplete* ERPT of around 10% when the daily NER changes exceed the threshold value of 0.55%, when only those goods for which the frequency of price change is above 3.12% are considered, and when only those goods with a storage potential higher than 10 weeks are considered. However, the ERPT for agricultural commodities is statistically insignificant when the corresponding variables obtain values below their corresponding threshold values. On the other hand, when only nonzero price changes are considered (in the spirit of Gopinath et al. (2010)), I find evidence for *complete* ERPT, given the confidence intervals of each point estimate contains the coefficient 1. The findings suggest that, on average, the ERPT coefficient is about 155% for agricultural commodities with a storage potential that is higher than 10 weeks, 120% for days when the exchange rate change is higher than 0.55%, and 73% for goods whose prices change more than 3.12% of the time.

These results are in line with the evidence in the literature and with economic theory. The finding that ERPT tends to be higher when exchange rate changes exceed a certain threshold is in line with the results in Burstein et al. (2005). They show that the magnitude of NER changes may be effective in the determination of ERPT.

The result linking the frequency of price change to the degree of ERPT is in line with the findings in Gopinath and Itskhoki (2010), who show a positive relationship between the frequency with which prices change and the magnitude of the ERPT.

In line with my findings, the authors of that paper find that, on average, goods with a high frequency of price adjustment have a long-run ERPT that is at least twice as high as that of those goods with low-frequency of adjustment.

The most novel finding of the chapter, which positively links the storage potential of an agricultural import and the degree of ERPT, is in line an economic channel in which the seller of a perishable good needs to sell the product as soon as possible, due to its high depreciation rate. This channel implies that sellers of more perishable commodities (i.e. those that are less “inventoriable” or those with lower storage potential) will be less inclined to try to pass-through their higher costs to consumers in the event of an exchange rate change. On the contrary, an importer of commodities with longer shelf lives may choose to pass-through her higher costs simply because she can afford to wait for an optimal price. Intuitively, since importers need to sell more perishable products (those with lower storage life) more quickly, they may optimally choose to take lower price offers, regardless of what happens to the exchange rate. This would imply an ERPT coefficient that is higher for more “storable” or less perishable products. Equivalently, this implies an ERPT coefficient that is lower for less “storable”, more perishable commodities, or goods with higher rates of depreciation, in general. This economic channel is in line with the studies of [Kryvtsov and Midrigan \(2012\)](#), and [Alessandria et al. \(2013\)](#), who show that the optimal price of a seller decreases as the depreciation rate of its inventories increase.

3.5 Conclusion

The appropriate design and implementation of monetary policy rests on the ability of policymakers to understand the extent to which external shocks reverberate

throughout the economy. This is particularly true in emerging market economies with inflation targeting frameworks. These economies are constantly subject to external shocks and policymakers are repeatedly facing policy trade-offs. An exchange rate shock, for instance, can pose several adverse macroeconomic consequences and a thorough understanding of these consequences is crucial. In particular, monetary policymakers in inflation targeting countries need to understand the extent to which changes in the nominal exchange rate may induce changes in consumer prices at home via the effect on the prices of imports. That is, policymakers need to have a full understanding of the extent of the exchange rate pass-through. This is crucial, because different degrees of ERPT will have different consequences for how monetary policy is communicated, how inflation expectations will be affected, and for the ability of policymakers to effectively have a countercyclical stance in response to shocks.

With this in mind, in this chapter I set out to measure the degree of ERPT in Turkey — an emerging market economy under inflation targeting and in which the nominal exchange rate has fluctuated wildly over the last decade. The chapter introduces a novel data set consisting of daily observations of wholesale prices of imported agricultural products into Turkey. This is one of the few available databases of import prices with observations at the daily frequency. The fact that these observations are daily allows me to study whether the degree of ERPT varies with the storage potential of the agricultural commodities, a link that has not been previously studied in the ERPT literature. One of the main advantages of the data is that its source also includes the prices for agricultural commodities domestically produced in Turkey and sold in Istanbul. This allows me to properly identify the effect of the exchange rate on the prices of imported products, since I can control

for all other local macroeconomic aspects that may affect the prices of agricultural commodities imported into Turkey.

The chapter contributes to a recent line of the literature that considers nonlinearities in the determination of the ERPT coefficient. In particular, several recent papers (e.g. [Shintani et al. \(2013\)](#), [Ben Cheikh and Rault \(2016\)](#), [Cheikh and Louhichi \(2016\)](#), [Donayre and Panovska \(2016\)](#)) have employed threshold models in order to understand whether the ERPT measure is higher or lower when the characteristics of interest exceed certain threshold levels. First, I use standard empirical methods commonly found in the ERPT literature to establish that the newly introduced data set shares in the empirical regularities typically found in the literature. Then, I go on to use a threshold model to study whether the ERPT coefficient varies when the magnitude of the exchange rate change, when the frequency of price change, or when the storage potential of the agricultural commodities exceed certain thresholds.

I find evidence for *incomplete* daily ERPT into agricultural import prices of about 5%. The incompleteness result is similar to those found in studies that use good-level data sets (e.g. see [Aron et al. \(2014\)](#), [Gopinath et al. \(2010\)](#), and [Lott and Einav \(2013\)](#)). However, the magnitude of the coefficients in this chapter are lower when compared to those in studies using more aggregated data (e.g. see [Goldberg and Knetter \(1996\)](#), and [Menon \(1995\)](#)).

Once nonlinearities are considered, the degree of ERPT into the prices of imported agricultural products doubles to about 10% when NER changes are larger than 0.55% daily, when the daily frequency of price change is above 3.12%, and when the storage potential of an agricultural commodity is above 10 weeks. The result that ERPT is higher when NER changes exceed a certain threshold is in line

with the findings in [Burstein et al. \(2005\)](#), who show that the magnitude of NER changes may be effective in the determination of ERPT.

The finding that the ERPT coefficient may depend on the frequency of price changes is in line with the findings in [Gopinath and Itskhoki \(2010\)](#), who show a positive relationship between the frequency with which prices change and the magnitude of the ERPT. In line with my findings, the authors of that study find that, on average, products with a high frequency of price adjustment have a long-run ERPT that is at least twice as high as that of those goods with low-frequency of adjustment.

The most novel finding of the chapter relates the degree of ERPT to the storage potential or to the rate of depreciation of the imported agricultural product. The finding positively links the storage potential of an agricultural commodity and its degree of ERPT. This is in line with an economic channel in which the seller of a perishable product needs to sell the good as soon as possible, due to its high depreciation rate. This implies that sellers of highly perishable products (those with lower storage potential or lower shelf life) will be less inclined to try to pass-through their higher costs to consumers in the event of an exchange rate shock. On the contrary, an importer of commodities with longer shelf lives may pass-through her higher costs simply because she can afford to wait for an optimal price. This channel is in line with the studies of [Kryvtsov and Midrigan \(2012\)](#), and [Alessandria et al. \(2013\)](#), who show that the optimal price of a seller decreases as the depreciation rate of its inventories increase.

The results presented in this chapter indicate that, overall and on average, ERPT is low for agricultural commodities in Turkey. This implies that in the event of nominal exchange rate shocks, Turkish policymakers may allow the exchange rate to move freely without fear that the prices of agricultural imports, and thereby of

consumer prices, will spike significantly. The nominal exchange rate can, therefore, facilitate the adjustment process of the real and the external sector of the economy to the shock, and Turkish policymakers can conduct monetary policy in an independent and countercyclical manner, in line with the requirements of the inflation targeting regime (see [Devereux et al. \(2006\)](#), and [Winkelried \(2014\)](#)).

Table 3.1: ERPT with Alternatives Exchange Rate Lags

VARIABLES	(1) Price	(2) Price	(3) Price	(4) Price	(5) Price	(6) Price	(7) Price	(8) Price	(9) Price
Exchange Rate	0.0490** (0.0230)	0.0438* (0.0255)	0.0520* (0.0271)	0.0598** (0.0272)	0.0623** (0.0291)	0.0585* (0.0300)	0.0616* (0.0314)	0.0594* (0.0325)	0.0582* (0.0337)
Exchange Rate, Lag 1		-0.0386 (0.0289)	-0.00581 (0.0289)	-0.0157 (0.0293)	-0.00894 (0.0278)	-0.0155 (0.0292)	-0.0166 (0.0294)	-0.0167 (0.0294)	-0.0238 (0.0294)
Exchange Rate, Lag 2			0.0542* (0.0296)	0.0795*** (0.0272)	0.0740*** (0.0268)	0.0546** (0.0269)	0.0507* (0.0291)	0.0526 (0.0315)	0.0451 (0.0312)
Exchange Rate, Lag 3				-0.00991 (0.0284)	0.000741 (0.0301)	2.69e-06 (0.0306)	-0.00303 (0.0291)	-0.000575 (0.0301)	-0.00185 (0.0303)
Exchange Rate, Lag 4					-0.00601 (0.0287)	-0.0257 (0.0275)	-0.0210 (0.0265)	-0.0273 (0.0270)	-0.0239 (0.0266)
Exchange Rate, Lag 5						0.0418 (0.0264)	0.0432 (0.0281)	0.0345 (0.0277)	0.0258 (0.0268)
Exchange Rate, Lag 6							-0.0362 (0.0217)	-0.0248 (0.0253)	-0.0255 (0.0262)
Exchange Rate, Lag 7								0.0194 (0.0309)	0.0179 (0.0327)
Exchange Rate, Lag 8									0.00297 (0.0229)
Inflation	0.335*** (0.0694)	0.325*** (0.0684)	0.328*** (0.0695)	0.334*** (0.0709)	0.339*** (0.0716)	0.344*** (0.0713)	0.334*** (0.0712)	0.336*** (0.0708)	0.335*** (0.0714)
Constant	-0.00435*** (0.000739)	-0.00361*** (0.000702)	-0.00372*** (0.000758)	-0.00396*** (0.000778)	-0.00293*** (0.000659)	-0.00353*** (0.000728)	-0.00361*** (0.000788)	-0.00372*** (0.000812)	-0.00410*** (0.000829)
Observations	37,806	36,950	36,058	35,164	34,291	33,503	32,743	31,997	31,253
R-squared	0.019	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021
Goods FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Seasonality	YES	YES	YES	YES	YES	YES	YES	YES	YES
AIC	-123466	-124685	-121932	-118911	-116218	-113645	-110946	-108199	-105873
BIC	-123312	-124523	-121762	-118733	-116032	-113452	-110744	-107989	-105656

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3.2: Alternative Controls

VARIABLES	(1) Price	(2) Price	(3) Price	(4) Price	(5) Price	(6) Price	(7) Price	(8) Price
Exchange Rate	0.0454* (0.0254)	0.0595* (0.0303)	0.0445* (0.0255)	0.0446* (0.0253)	0.0438* (0.0255)	0.0580* (0.0303)	0.0584* (0.0305)	0.0567* (0.0305)
Exchange Rate, Lag 1	-0.0363 (0.0278)	-0.0410 (0.0284)	-0.0382 (0.0289)	-0.0367 (0.0277)	-0.0386 (0.0289)	-0.0421 (0.0283)	-0.0435 (0.0294)	-0.0446 (0.0293)
Inflation	0.351*** (0.0737)	0.400*** (0.0857)	0.325*** (0.0683)	0.350*** (0.0740)	0.325*** (0.0684)	0.400*** (0.0860)	0.374*** (0.0801)	0.374*** (0.0803)
Constant	0.000269* (0.000136)	0.000201*** (2.98e-05)	-0.00227*** (0.000746)	-0.00122*** (0.000261)	-0.00361*** (0.000702)	-0.00138*** (0.000302)	-0.00212** (0.000941)	-0.00377*** (0.000877)
Observations	36,950	25,082	36,950	36,950	36,950	25,082	25,082	25,082
R-squared	0.017	0.023	0.020	0.018	0.021	0.024	0.027	0.028
AIC	-124572	-85889	-124656	-124599	-124685	-85919	-85962	-85994
BIC	-124538	-85832	-124486	-124574	-124523	-85895	-85775	-85840
Perishability		YES				YES	YES	YES
Seasonality			YES		YES		YES	YES
Goods FE				YES	YES	YES		YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3.3: ERPT in Different Years

VARIABLES	(1) Price	(2) Price	(3) Price	(4) Price	(5) Price	(6) Price	(7) Price	(8) Price	(9) Price	(10) Price	(11) Price
Exchange Rate	-0.0354 (0.121)	-0.108 (0.0730)	-0.00401 (0.111)	-0.0503 (0.0556)	0.231** (0.0926)	0.379** (0.157)	-0.0778 (0.155)	-0.172 (0.190)	-0.0199 (0.151)	0.116 (0.0970)	0.290** (0.135)
Inflation	0.0353 (0.0736)	0.159* (0.0882)	0.116*** (0.0375)	0.358*** (0.107)	0.397** (0.162)	0.476*** (0.121)	0.517*** (0.147)	0.397*** (0.136)	0.448*** (0.116)	0.428*** (0.128)	0.126 (0.115)
Constant	-0.0183 (0.0126)	0.000395 (0.00217)	-0.00127 (0.00114)	-0.00986*** (0.00332)	-0.000845 (0.00209)	-0.00252 (0.00226)	-0.00808*** (0.00191)	-0.00486 (0.00287)	0.00223 (0.00198)	0.000920 (0.00202)	-0.00849*** (0.00286)
Observations	3,173	2,516	3,102	3,156	3,478	3,389	3,973	3,918	3,886	4,209	3,006
R-squared	0.010	0.016	0.022	0.044	0.030	0.040	0.029	0.031	0.022	0.033	0.051
Goods FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Seasonality	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
AIC	-8233	-10244	-11867	-10174	-11732	-10704	-13019	-12825	-13065	-14814	-9097
BIC	-8124	-10139	-11758	-10071	-11621	-10593	-12912	-12712	-12953	-14700	-9006

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3.4: ERPT: Threshold on Exchange Rate Changes, All Price Changes.

VARIABLES	(1) Price	(2) Price	(3) Price	(4) Price
Inflation		0.358*** (0.0745)		0.335*** (0.0694)
High Exchange Rate Changes	0.0971*** (0.0362)	0.0988*** (0.0368)	0.112*** (0.0383)	0.110*** (0.0389)
Low Exchange Rate Changes	-0.00804 (0.0381)	0.000435 (0.0391)	-0.0266 (0.0382)	-0.0166 (0.0392)
Constant	-0.000311 (0.000200)	-6.63e-05 (0.000213)	-0.00460*** (0.000824)	-0.00468*** (0.000821)
Observations	37,806	37,806	37,806	37,806
R-squared	0.000	0.016	0.007	0.019
AIC	-122766	-123365	-122978	-123467
BIC	-122740	-123331	-122824	-123305
Goods FE			YES	YES
Seasonality			YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: Threshold value at 0.55%. High and low exchange rate changes correspond to exchange rate changes above and below the threshold value. No restrictions on price changes.

Table 3.5: ERPT with Threshold on Exchange Rate Changes, Nonzero Price Changes.

VARIABLES	(1) Price	(2) Price	(3) Price	(4) Price
Inflation		1.862*** (0.143)		1.680*** (0.101)
High Exchange Rate Changes	0.916** (0.400)	1.168** (0.462)	1.032** (0.452)	1.201** (0.494)
Low Exchange Rate Changes	-0.0527 (0.407)	0.108 (0.361)	-0.236 (0.368)	-0.0329 (0.342)
Constant	-0.00280 (0.00214)	-0.00250 (0.00215)	-0.0452*** (0.0165)	-0.0384** (0.0152)
Observations	3,989	3,989	3,989	3,989
R-squared	0.001	0.084	0.057	0.116
AIC	-3981	-4322	-4182	-4434
BIC	-3963	-4297	-4069	-4315
Goods FE			YES	YES
Seasonality			YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: Threshold value at 0.55%. High and low exchange rate changes correspond to exchange rate changes above and below the threshold value. Only nonzero price changes.

Table 3.6: ERPT with Threshold on Frequency of Price Changes, All Price Changes.

VARIABLES	(1) Price	(2) Price	(3) Price	(4) Price
Inflation		0.358*** (0.0745)		0.335*** (0.0694)
Exchange Rate x High Frequency	0.0860*** (0.0239)	0.0928*** (0.0245)	0.0856*** (0.0241)	0.0905*** (0.0245)
Exchange Rate x Low Frequency	-0.0292 (0.0318)	-0.0278 (0.0331)	-0.0327 (0.0319)	-0.0307 (0.0328)
Constant	-9.05e-05 (0.000124)	0.000140 (0.000141)	-0.00433*** (0.000741)	-0.00445*** (0.000745)
Observations	37,806	37,806	37,806	37,806
R-squared	0.000	0.016	0.007	0.019
AIC	-122767	-123366	-122978	-123468
BIC	-122741	-123332	-122824	-123305
Goods FE			YES	YES
Seasonality			YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: Threshold value at 3.12%. High and low frequency of price changes correspond to a frequency of price change above and below the threshold value. No restrictions on price changes.

Table 3.7: ERPT with Threshold on Frequency of Price Changes, Nonzero Price Changes.

VARIABLES	(1) Price	(2) Price	(3) Price	(4) Price
Inflation		1.856*** (0.142)		1.674*** (0.0993)
Exchange Rate x High Frequency	0.619*** (0.221)	0.768*** (0.278)	0.607** (0.272)	0.732** (0.317)
Exchange Rate x Low Frequency	-1.504 (1.759)	-0.456 (1.554)	-1.736 (1.746)	-0.712 (1.521)
Constant	-0.000940 (0.00130)	-0.000462 (0.00135)	-0.0428*** (0.0156)	-0.0361** (0.0143)
Observations	3,989	3,989	3,989	3,989
R-squared	0.002	0.083	0.058	0.115
AIC	-3983	-4321	-4183	-4432
BIC	-3964	-4296	-4070	-4313
Goods FE			YES	YES
Seasonality			YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: Threshold value at 3.12%. High and low frequency of price changes correspond to a frequency of price change above and below the threshold value. Only nonzero price changes.

Table 3.8: ERPT with Threshold on Storage Potential, All Prices

VARIABLES	(1) Price	(2) Price	(3) Price	(4) Price
Inflation		0.358*** (0.0745)		0.335*** (0.0694)
Exchange Rate x Low Storage Pot.	0.0336 (0.0258)	0.0377 (0.0269)	0.0326 (0.0262)	0.0356 (0.0269)
Exchange Rate x High Storage Pot.	0.0899** (0.0367)	0.0980** (0.0379)	0.0870** (0.0356)	0.0940** (0.0361)
Constant	-8.81e-05 (0.000124)	0.000142 (0.000140)	-0.00425*** (0.000738)	-0.00436*** (0.000741)
Observations	37,806	37,806	37,806	37,806
R-squared	0.000	0.016	0.006	0.019
AIC	-122764	-123363	-122975	-123464
BIC	-122739	-123329	-122821	-123302
Goods FE			YES	YES
Seasonality			YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Threshold value at 10 weeks. Goods with Low Storage Potential are those with a storage potential that is less than or equal to the threshold value, while goods with High Storage Potential are those with a storage potential that is strictly greater than the threshold value. No restrictions on price changes.

Table 3.9: ERPT with Threshold on Storage Potential, Nonzero Prices

VARIABLES	(1) Price	(2) Price	(3) Price	(4) Price
Inflation		1.862*** (0.141)		1.682*** (0.0989)
Exchange Rate x Low Storage Pot.	0.325 (0.223)	0.513* (0.259)	0.266 (0.247)	0.432 (0.280)
Exchange Rate x High Storage Pot.	1.132* (0.606)	1.441** (0.696)	1.289** (0.507)	1.553** (0.647)
Constant	-0.000901 (0.00127)	-0.000423 (0.00134)	-0.0428*** (0.0156)	-0.0361** (0.0143)
Observations	3,989	3,989	3,989	3,989
R-squared	0.001	0.083	0.057	0.115
AIC	-3980	-4321	-4181	-4433
BIC	-3962	-4296	-4067	-4314
Goods FE			YES	YES
Seasonality			YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Threshold value at 10 weeks. Goods with Low Storage Potential are those with a storage potential that is less than or equal to the threshold value, while goods with High Storage Potential are those with a storage potential that is strictly greater than the threshold value. Only nonzero price changes.

Table 3.10: ERPT and Thresholds - Summary Table

VARIABLES	Dependent Variable: Δ Log Daily Product-level Price					
	All Price Changes			Non-zero Price Changes		
	(1)	(2)	(3)	(4)	(5)	(6)
Δ Log Daily Exchange Rate > Threshold of 0.55%	0.110*** (0.0389)			1.201** (0.494)		
Δ Log Daily Exchange Rate $\leq$ Threshold of 0.55%	-0.0166 (0.0392)			-0.0329 (0.342)		
(Δ Log Daily Exchange Rate) x (Frequency of Price Change > Threshold of 3.12%)		0.0905*** (0.0245)			0.732** (0.317)	
(Δ Log Daily Exchange Rate) x (Frequency of Price Change $\leq$ Threshold of 3.12%)		-0.0307 (0.0328)			-0.712 (1.521)	
(Δ Log Daily Exchange Rate) x (Storage Life > Threshold of 10 weeks)			0.0940** (0.0361)			1.553** (0.647)
(Δ Log Daily Exchange Rate) x (Storage Life $\leq$ Threshold of 10 weeks)			0.0356 (0.0269)			0.432 (0.280)
Daily Domestic Inflation	0.335*** (0.0694)	0.335*** (0.0694)	0.335*** (0.0694)	1.680*** (0.101)	1.674*** (0.0993)	1.681*** (0.0999)
Goods FE	YES	YES	YES	YES	YES	YES
Seasonality	YES	YES	YES	YES	YES	YES
AIC	-123467	-123468	-123464	-4434	-4432	-4431
BIC	-123305	-123305	-123302	-4315	-4313	-4311
R-squared	0.019	0.019	0.019	0.116	0.115	0.115
Observations	37,806	37,806	37,806	3,989	3,989	3,989

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Figure 3.1: Exchange Rate over Time: Turkish Lira per U.S. Dollar

Figure 3.2: Fixed Effects: Exchanges Rates Changes vs Ramadan

Note: Observations of daily log exchange rate changes in Ramadan vs non-Ramadan days.

Figure 3.3: Fixed Effects: Exchanges Rates Changes vs Weekdays

Note: Observations of daily log exchange rate changes each weekday.

Figure 3.4: Fixed Effects: Exchanges Rates Changes vs Months

Note: Observations of daily log exchange rate changes each month.

Figure 3.5: Fixed Effects: Exchanges Rates Changes vs Years

Note: Observations of daily log exchange rate changes each year.

Figure 3.6: Fixed Effects: Price Changes vs Ramadan

Note: Observations of daily log price changes in Ramadan vs non-Ramadan days.

Figure 3.7: Fixed Effects: Price Changes vs Weekdays

Note: Observations of daily log price changes each weekday.

Figure 3.8: Fixed Effects: Price Changes vs Months

Note: Observations of daily log price changes each month.

Figure 3.9: Fixed Effects: Price Changes vs Years

Note: Observations of daily log price changes each year.

Figure 3.10: Threshold Analysis: Exchange Rate Change

Note: Residual Sum of Squares (RSS) over all possible values of the exchange rate change threshold.

Figure 3.11: Threshold Analysis: Frequency of Price Change

Note: Residual Sum of Squares (RSS) over all possible values of the frequency of price change threshold.

Figure 3.12: Threshold Analysis: Storage Potential

Note: Residual Sum of Squares (RSS) over all possible values of the storage potential threshold.

REFERENCES

- Abbritti, Mirko and Sebastian Weber (2018), “Reassessing the role of labor market institutions for the business cycle.” *International Journal of Central Banking*, 14, 1–34.
- Adler, Gustavo, Noemie Lisack, and Rui Mano (2015), “Unveiling the effects of foreign exchange intervention: A panel approach.” IMF Working Paper 15/130.
- Adler, Gustavo and Rui C Mano (2018), “The cost of foreign exchange intervention: Concepts and measurement.” *Journal of Macroeconomics*.
- Adler, Gustavo and Camilo E Tovar (2011), “Foreign exchange intervention: A shield against appreciation winds?” IMF Working Paper 11/165.
- Aghion, Philippe, Philippe Bacchetta, Romain Ranciere, and Kenneth Rogoff (2009), “Exchange rate volatility and productivity growth: The role of financial development.” *Journal of monetary economics*, 56, 494–513.
- Airaud, Marco (2016), “Inflation targeting and exchange rate management in less developed countries.” IMF Working Paper 16/55.
- Aizenman, Joshua, Sebastian Edwards, and Daniel Riera-Crichton (2012), “Adjustment patterns to commodity terms of trade shocks: the role of exchange rate and international reserves policies.” *Journal of International Money and Finance*, 31, 1990–2016.
- Al-Ississ, Mohamad (2010), “The impact of religious experience on financial markets.” *International Review of Financial Analysis*, 17, 461–474.
- Alessandria, George, Joseph Kaboski, and Virgiliu Midrigan (2013), “Trade wedges, inventories, and international business cycles.” *Journal of Monetary Economics*, 60, 1–20.
- Ali, Irfan, Waheed Akhter, and Namrah Ashraf (2017), “Impact of muslim holy days on asian stock markets: An empirical evidence.” *Cogent Economics & Finance*, 5, 1311096.
- Anderson, James E and Eric Van Wincoop (2004), “Trade costs.” *Journal of Economic literature*, 42, 691–751.
- Appelbaum, Binyamin (2016), “Outspoken fed official frets about following japan’s path.” *New York Times*. May 4.
- Aron, Janine, Greg Farrell, John Muellbauer, and Peter Sinclair (2014), “Exchange rate pass-through to import prices, and monetary policy in south africa.” *Journal of Development Studies*, 50, 144–164.

- Ascari, Guido (2004), “Staggered prices and trend inflation: some nuisances.” *Review of Economic dynamics*, 7, 642–667.
- Ascari, Guido and Tiziano Ropele (2007), “Optimal monetary policy under low trend inflation.” *Journal of Monetary Economics*, 54, 2568–2583.
- Ascari, Guido and Argia M Sbordone (2014), “The macroeconomics of trend inflation.” *Journal of Economic Literature*, 52, 679–739.
- Atkeson, Andrew and Ariel T Burstein (2011), “Aggregate implications of innovation policy.” Technical report, National Bureau of Economic Research.
- Azzimonti, Marina (2011), “Barriers to investment in polarized societies.” *American Economic Review*, 101, 2182–2204.
- Bakhshi, Hasan, Hashmat Khan, Pablo Burriel-Llombart, and Barbara Rudolf (2007), “The new keynesian phillips curve under trend inflation and strategic complementarity.” *Journal of macroeconomics*, 29, 37–59.
- Baldwin, Richard and Simon Evenett (2011), *The collapse of global trade, murky protectionism and the crisis: Recommendations for the G20*. Cepr.
- Baldwin, Richard and Lucrezia Reichlin (2013), “Is inflation targeting dead.” *Central Banking After the Crisis*, Centre for Economic Policy Research.
- Ball, Laurence M (2013), “The case for four percent inflation.” *Central Bank Review*, 13, 17.
- Banco Central de Chile (2007), “Central Bank of Chile: Monetary Policy in an Inflation Targeting Framework.” January.
- Bems, Rudolf, Francesca Caselli, Francesco Grigoli, Bertrand Gruss, and Lian Weicheng (2018), “Is inflation domestic or global? evidence from emerging markets.” IMF Working Paper 18/241.
- Ben Cheikh, Nidhaleddine and Christophe Rault (2016), “The pass-through of exchange rate in the context of the european sovereign debt crisis.” *International Journal of Finance & Economics*, 21, 154–166.
- Ben Cheikh, Nidhaleddine and Christophe Rault (2017), “Investigating first-stage exchange rate pass-through: Sectoral and macro evidence from euro area countries.” *The World Economy*, 40, 2611–2638.
- Benigno, Gianluca (2004), “Real exchange rate persistence and monetary policy rules.” *Journal of Monetary Economics*, 51, 473–502.

- Benigno, Gianluca and Pierpaolo Benigno (2008), “Exchange rate determination under interest rate rules.” *Journal of international Money and Finance*, 27, 971–993.
- Berganza, Juan Carlos and Carmen Broto (2012), “Flexible inflation targets, forex interventions and exchange rate volatility in emerging countries.” *Journal of International Money and Finance*, 31, 428–444.
- Blanchard, Olivier, Gustavo Adler, and Irineu de Carvalho Filho (2015), “Can foreign exchange intervention stem exchange rate pressures from global capital flow shocks?” IMF Working Paper 15/159.
- Blanchard, Olivier, Giovanni Dell’Ariccia, and Paolo Mauro (2010), “Rethinking macroeconomic policy1.” *Rethinking Macroeconomic Policy*, 2010, 2–19.
- Blinder, Alan S (2000), “Central-bank credibility: why do we care? how do we build it?” *American Economic Review*, 90, 1421–1431.
- Boffa, Mauro, Matthias Helble, et al. (2014), “A short-run analysis of exchange rates and international trade with an application to australia, new zealand, and japan.” Technical report, East Asian Bureau of Economic Research.
- Bordo, Michael and Pierre Siklos (2014), “Central bank credibility, reputation and inflation targeting in historical perspective.” NBER Working Paper 20693.
- Bordo, Michael D and Pierre L Siklos (2015), “Central bank credibility: An historical and quantitative exploration.” Technical report. NBER Working Paper 20824.
- Bordo, Michael D and Pierre L Siklos (2017), “Central bank credibility before and after the crisis.” *Open Economies Review*, 28, 19–45.
- Bowen, T Renee, Ying Chen, and Hülya Eraslan (2014), “Mandatory versus discretionary spending: The status quo effect.” *American Economic Review*, 104, 2941–74.
- Bullard, James (2011), “Measuring inflation: the core is rotten.” *Federal Reserve Bank of St. Louis Review*, 93, 223–233.
- Burstein, Ariel, Martin Eichenbaum, and Sergio Rebelo (2005), “Large devaluations and the real exchange rate.” *Journal of political Economy*, 113, 742–784.
- Burstein, Ariel and Gita Gopinath (2014), “International prices and exchange rates.” In *Handbook of International Economics*, volume 4, 391–451, Elsevier.
- Calvo, Guillermo A (1983), “Staggered prices in a utility-maximizing framework.” *Journal of monetary Economics*, 12, 383–398.

- Calvo, Guillermo A and Carmen M Reinhart (2002), “Fear of floating.” *The Quarterly Journal of Economics*, 117, 379–408.
- Campa, Jose Manuel and Linda S Goldberg (2005), “Exchange rate pass-through into import prices.” *Review of Economics and Statistics*, 87, 679–690.
- Cantwell, Marita (2001), “Properties and recommended conditions for long-term storage of fresh fruits and vegetables.”, URL <http://postharvest.ucdavis.edu>.
- Cashin, Paul, Luis F Céspedes, and Ratna Sahay (2004), “Commodity currencies and the real exchange rate.” *Journal of Development Economics*, 75, 239–268.
- Catalán-Herrera, Juan (2016), “Foreign exchange market interventions under inflation targeting: The case of Guatemala.” *Journal of International Financial Markets, Institutions and Money*, 42, 101–114.
- Cecchetti, Stephen G and Stefan Krause (2002), “Central bank structure, policy efficiency, and macroeconomic performance: exploring empirical relationships.” *Review-Federal Reserve Bank of Saint Louis*, 84, 47–60.
- Central Reserve Bank of Peru (2007), “Inflation Report - Recent Trends and Macroeconomic Forecasts.” January.
- Chan, Kung-Sik et al. (1993), “Consistency and limiting distribution of the least squares estimator of a threshold autoregressive model.” *The Annals of Statistics*, 21, 520–533.
- Cheikh, Nidhaleddine Ben and Wael Louhichi (2016), “Revisiting the role of inflation environment in exchange rate pass-through: A panel threshold approach.” *Economic Modelling*, 52, 233–238.
- Chen, Yu-chin and Kenneth Rogoff (2003), “Commodity currencies.” *Journal of International Economics*, 60, 133–160.
- Chen, Yu-Chin, Kenneth S Rogoff, and Barbara Rossi (2010), “Can exchange rates forecast commodity prices?” *The Quarterly Journal of Economics*, 125, 1145–1194.
- Cole, Harold L and Maurice Obstfeld (1991), “Commodity trade and international risk sharing: How much do financial markets matter?” *Journal of Monetary Economics*, 28, 3–24.
- Daude, Christian, Eduardo Levy Yeyati, and Arne J Nagengast (2016), “On the effectiveness of exchange rate interventions in emerging markets.” *Journal of International Money and Finance*, 64, 239–261.

- Deaton, A and R Miller (1996), “International commodity prices, macroeconomic performance and politics in sub-saharan africa.” *Journal of African Economies*, 5, 99–191.
- Debortoli, Davide, Jinill Kim, Jesper Lindé, and Ricardo Nunes (2018), “Designing a simple loss function for central banks: Does a dual mandate make sense?” *The Economic Journal*.
- Demertzis, Maria, Massimiliano Marcellino, and Nicola Viegi (2012), “A credibility proxy: Tracking us monetary developments.” *The BE Journal of Macroeconomics*, 12.
- Devereux, Michael B, Philip R Lane, and Juanyi Xu (2006), “Exchange rates and monetary policy in emerging market economies.” *The Economic Journal*, 116, 478–506.
- Devereux, Michael B and Gregor W Smith (2018), “Commodity currencies and monetary policy.” NBER Working Paper 25076.
- Donayre, Luigi and Irina Panovska (2016), “State-dependent exchange rate pass-through behavior.” *Journal of International Money and Finance*, 64, 170–195.
- Engel, Charles (2013), “Exchange rates and interest parity.” Technical report, National Bureau of Economic Research.
- Ferraro, Domenico, Kenneth Rogoff, and Barbara Rossi (2015), “Can oil prices forecast exchange rates? an empirical analysis of the relationship between commodity prices and exchange rates.” *Journal of International Money and Finance*, 54, 116–141.
- Galí, Jordi (2015), *Monetary policy, inflation, and the business cycle: an introduction to the new Keynesian framework and its applications*. Princeton University Press.
- Gali, Jordi and Tommaso Monacelli (2005), “Monetary policy and exchange rate volatility in a small open economy.” *The Review of Economic Studies*, 72, 707–734.
- Ghosh, Atish R, Jonathan D Ostry, and Marcos Chamon (2016), “Two targets, two instruments: monetary and exchange rate policies in emerging market economies.” *Journal of International Money and Finance*, 60, 172–196.
- Gillitzer, Christian, John Simon, et al. (2015), “Inflation targeting: A victim of its own success?” *International Journal of Central Banking*, 11, 259–287.
- Goldberg, Pinelopi K and Michael M Knetter (1996), “Goods prices and exchange rates: What have we learned?” NBER Working Paper N. 5862.

- Gonçalves, Carlos Eduardo S and João M Salles (2008), “Inflation targeting in emerging economies: What do the data say?” *Journal of Development Economics*, 85, 312–318.
- Goodfriend, Marvin and Robert G King (2001), “The case for price stability.” Technical report, National Bureau of Economic Research.
- Gopinath, Gita (2015), “The international price system.” NBER Working Paper Series, No. 21646.
- Gopinath, Gita and Oleg Itskhoki (2010), “Frequency of price adjustment and pass-through.” *The Quarterly Journal of Economics*, 125.
- Gopinath, Gita, Oleg Itskhoki, and Roberto Rigobon (2010), “Currency choice and exchange rate pass-through.” *American Economic Review*, 100, 304–336.
- Gruss, Bertrand (2014), “After the boom: Commodity prices and economic growth in latin america and the caribbean.” IMF Working Paper 14/154.
- Ha, Jongrim, M. Ayhan Kose, Franziska Ohnsorge, and Hakan Yilmazkuday (2018), “Sources of inflation: Global and domestic drivers.” In *Inflation in Emerging and Developing Economies Evolution, Drivers, and Policies* (Jongrim Ha, M. Ayhan Kose, and Franziska Ohnsorge, eds.), chapter 3, 143–199, World Bank Publications, Washington DC.
- Hansen, Bruce E (1999), “Threshold effects in non-dynamic panels: Estimation, testing, and inference.” *Journal of econometrics*, 93, 345–368.
- Hansen, Bruce E (2000), “Sample splitting and threshold estimation.” *Econometrica*, 68, 575–603.
- He, Zhiguo and Arvind Krishnamurthy (2013), “Intermediary asset pricing.” *American Economic Review*, 103, 732–70.
- Ihrig, Jane, Steven B Kamin, Deborah Lindner, and Jaime Marquez (2010), “Some simple tests of the globalization and inflation hypothesis.” *International Finance*, 13, 343–375.
- IMF (2012), *Growth Resuming, Dangers Remain. World Economic Outlook, April*. International Monetary Fund, Washington, D.C.
- IMF (2015), *Adjusting to Lower Commodity Prices. World Economic Outlook, October*. International Monetary Fund, Washington, D.C.
- IMF (2017), “Selected decisions and selected documents of the international monetary fund.” 39th Issue, Washington DC.

- IMF (2018a), *Challenges to Steady Growth. World Economic Outlook, October*. International Monetary Fund, Washington, D.C.
- IMF (2018b), *Seizing the Momentum. Regional Economic Outlook: Western Hemisphere, April*. International Monetary Fund, Washington, D.C.
- Kamil, Herman (2008), “Is central bank intervention effective under inflation targeting regimes? The case of Colombia.” IMF Working Paper 08/88.
- King, Robert G and Alexander L Wolman (1996), “Inflation targeting in a st. louis model of the 21st century.” Technical report, National bureau of economic research.
- Kryvtsov, Oleksiy and Virgiliu Midrigan (2012), “Inventories, markups, and real rigidities in menu cost models.” *Review of Economic Studies*, 80, 249–276.
- Levieuge, Grégory, Yannick Lucotte, and Sébastien Ringuedé (2018), “Central bank credibility and the expectations channel: Evidence based on a new credibility index.” *Review of World Economics*, 154, 493–535.
- Levy-Yeyati, Eduardo, Federico Sturzenegger, and Pablo Alfredo Gluzmann (2013), “Fear of appreciation.” *Journal of Development Economics*, 101, 233–247.
- Lott, Zachariah and Liran Einav (2013), “Exchange rate pass-through on ebay.”
- Mendoza, Enrique G (1995), “The terms of trade, the real exchange rate, and economic fluctuations.” *International Economic Review*, 101–137.
- Menon, Jayant (1995), “Exchange rate pass-through.” *Journal of Economic Surveys*, 9, 197–231.
- Mihalke, D (2005), “Survey of central banks’ views on effects of intervention.” *BIS Papers*, 24.
- Mishkin, Frederic S (2000), “Inflation targeting in emerging-market countries.” *American Economic Review*, 90, 105–109.
- Mishkin, Frederic S and Miguel A Savastano (2001), “Monetary policy strategies for latin america.” *Journal of Development Economics*, 66, 415 – 444.
- Monacelli, Tommaso (2001), “New international monetary arrangements and the exchange rate.” *International Journal of Finance & Economics*, 6, 389–400.
- Nazlioglu, Saban and Ugur Soytaş (2011), “World oil prices and agricultural commodity prices: evidence from an emerging market.” *Energy Economics*, 33, 488–496.

- Neely, Christopher J. (2001), “The practice of central bank intervention: looking under the hood.” *Federal Reserve Bank of St. Louis Review*, 1–10.
- Neuenkirch, Matthias and Peter Tillmann (2014), “Inflation targeting, credibility, and non-linear taylor rules.” *Journal of International Money and Finance*, 41, 30–45.
- Nordstrom, Anna, Mr Scott Roger, Mr Mark R Stone, Seiichi Shimizu, Turgut Kisinbay, and Jorge Restrepo (2009), *The Role of the Exchange Rate in Inflation: Targeting Emerging Economies*. 267, International Monetary Fund.
- Novy, Dennis (2013), “Gravity redux: measuring international trade costs with panel data.” *Economic inquiry*, 51, 101–121.
- Obstfeld, Maurice and Kenneth Rogoff (2000), “The six major puzzles in international macroeconomics: is there a common cause?” *NBER macroeconomics annual*, 15, 339–390.
- Obstfeld, Maurice and Kenneth Rogoff (2001), “The six major puzzles in international macroeconomics: is there a common cause?” In *NBER Macroeconomics Annual 2000, Volume 15*, 339–412, MIT press.
- Ogrokhina, Olena and Cesar M Rodriguez (2018), “The role of inflation targeting in international debt denomination in developing countries.” *Journal of International Economics*, 114, 116–129.
- Paloviita, Maritta, Markus Haavio, Pirkka Jalasjoki, and Juha Kilponen (2017), “What does ‘below, but close to, two percent’ mean? assessing the ecb’s reaction function with real time data.” Bank of Finland Research Discussion Paper 29/2017.
- Richards, Peter D, Robert J Myers, Scott M Swinton, and Robert T Walker (2012), “Exchange rates, soybean supply response, and deforestation in south america.” *Global environmental change*, 22, 454–462.
- Rose, Andrew K (2007), “A stable international monetary system emerges: Inflation targeting is bretton woods, reversed.” *Journal of International Money and Finance*, 26, 663–681.
- Runkle, David E (1987), “Vector autoregressions and reality.” *Journal of Business & Economic Statistics*, 5, 437–442.
- Sarno, Lucio and Mark P Taylor (2001), “Official intervention in the foreign exchange market: is it effective and, if so, how does it work?” *journal of Economic Literature*, 39, 839–868.

- Schaffnit-Chatterjee, Claire, Stefan Schneider, Manuela Peter, and Thomas Mayer (2010), “Risk management in agriculture.” *Deutsche Bank Research*. Sept.
- Schmitt-Grohe, Stephanie, Martin Uribe, et al. (2007), “Optimal inflation stabilization in a medium-scale macroeconomic model.” *Monetary policy under inflation targeting*, 125–186.
- Shintani, Mototsugu, Akiko Terada-Hagiwara, and Tomoyoshi Yabu (2013), “Exchange rate pass-through and inflation: A nonlinear time series analysis.” *Journal of International Money and Finance*, 32, 512–527.
- Silver, Mick (2009), “Do unit value export, import, and terms-of-trade indices misrepresent price indices?” *IMF Staff Papers*, 56, 297–322.
- Smets, Frank et al. (2014), “Financial stability and monetary policy: How closely interlinked?” *International Journal of Central Banking*, 10, 263–300.
- Song, Zheng, Kjetil Storesletten, and Fabrizio Zilibotti (2012), “Rotten parents and disciplined children: A politico-economic theory of public expenditure and debt.” *Econometrica*, 80, 2785–2803.
- Towbin, Pascal and Sebastian Weber (2013), “Limits of floating exchange rates: The role of foreign currency debt and import structure.” *Journal of Development Economics*, 101, 179–194.
- Vegh, Carlos A and Guillermo Vuletin (2014), “Overcoming the fear of free falling: Monetary policy graduation in emerging markets.” *Role Of Central Banks In Financial Stability, The: How Has It Changed?*, 30, 105.
- Winkelried, Diego (2014), “Exchange rate pass-through and inflation targeting in peru.” *Empirical Economics*, 46, 1181–1196.
- Woodford, Michael (2003), *Interest and prices*. Princeton University Press.

APPENDICES

A Chapter 1 Appendix

Figures for all countries

Figure A.1: Inflation Targets, Expected Inflation, and Observed Inflation.

Note: One year ahead inflation expectations data available for EM7 only: Brazil, Chile, Colombia, Guatemala, Peru, Mexico, and Turkey. Inflation targets are those announced by each country's Central Bank. Year-on-year inflation refers to the CPI inflation rate from the corresponding quarter the previous year.

Figure A.2: Inflation Expectations Gap and Observed Inflation Gap.

Note: The figure plots the credibility measures $CRED^{EGap}$ and $CRED^{YoY}$. The $CRED^{EGap}$ measure is plotted only for countries for which inflation expectations data is available; i.e. for EM7 countries only: Brazil, Chile, Colombia, Guatemala, Mexico, Peru, and Turkey.

Figure A.3: Credibility Index: $CRED^{LLR}$

Note: $CRED^{LLR}$ is an expectations-based credibility measure as proposed by [Levieuge et al. \(2018\)](#). The index falls between 0 (implying total loss of credibility) to 1 (implying full credibility). $CRED^{LLR}$ is plotted only for countries for which inflation expectations data is available; i.e. for EM7 countries only: Brazil, Chile, Colombia, Guatemala, Mexico, Peru, and Turkey.

Figure A.4: Commodity Prices Indexes: Country-specific and Broader Indexes

Note: The figure displays the country-specific commodity export price index, $CMX_{i,t}$, along with a set of not-country-specific price indexes for broad categories of commodities. All indexes are set to 100 in 2005Q1.

Figure A.5: Commodity Prices and the Exchange Rate.

Note: The country-specific commodity export price index, $CMX_{i,t}$, along with an index of the nominal exchange rate. Both indexes are set to 100 in 2005Q1.

Extended IRFs

Figure A.6: Foreign Exchange Intervention: $FXI_{i,t}^{RA}$

Note: Dynamic response to a 10 percent commodity export price shock for different levels of foreign exchange intervention. Using $FXI_{i,t}^{RA}$. Countries: Brazil, Chile, Colombia, Guatemala, Mexico, Peru, and Turkey.

Figure A.7: Foreign Exchange Intervention: $FXI_{i,t}^{LYS}$

Note: Dynamic response to a 10 percent commodity export price shock for different levels of foreign exchange intervention. Using $FXI_{i,t}^{LYS}$ Countries: Brazil, Chile, Colombia, Guatemala, Mexico, Peru, and Turkey.

Figure A.8: Central Bank Credibility: $CRED_{i,t}^{EGap}$

Note: Dynamic response to a 10 percent commodity export price shock for different levels of central bank credibility. Using the $CRED_{i,t}^{EGap}$ credibility measure. Countries: Brazil, Chile, Colombia, Guatemala, Mexico, Peru, and Turkey.

Figure A.9: Central Bank Credibility: $CRED_{i,t}^{LLR}$

Note: Dynamic response to a 10 percent commodity export price shock for different levels of central bank credibility. Using the $CRED_{i,t}^{LLR}$ credibility measure. Countries: Brazil, Chile, Colombia, Guatemala, Mexico, Peru, and Turkey.

Figure A.10: FXI and Central Bank Credibility: $FXI_{i,t}^{RA}$ and $CRED_{i,t}^{LLR}$

Note: Response to a 10 percent Commodity Export Price Shock. Using $FXI_{i,t}^{RA}$ and $CRED_{i,t}^{LLR}$ credibility measure. Countries: Brazil, Chile, Colombia, Guatemala, Mexico, Peru, and Turkey.

Figure A.11: FXI and Central Bank Credibility: $FXI_{i,t}^{LYS}$ and $CRED_{i,t}^{EGap}$

Note: Response to a 10 percent Commodity Export Price Shock. Using $FXI_{i,t}^{LYS}$ and $CRED_{i,t}^{EGap}$ credibility measure. Countries: Brazil, Chile, Colombia, Guatemala, Mexico, Peru, and Turkey.

Figure A.12: FXI and Central Bank Credibility: $FXI_{i,t}^{LYS}$ and $CRED_{i,t}^{LLR}$

Note: Response to a 10 percent Commodity Export Price Shock. Using $FXI_{i,t}^{LYS}$ and $CRED_{i,t}^{LLR}$ credibility measure. Countries: Brazil, Chile, Colombia, Guatemala, Mexico, Peru, and Turkey.

Figure A.13: Central Bank Credibility: $CRED_{i,t}^{YoY}$

Note: Dynamic response to a 10 percent commodity export price shock for different levels of central bank credibility. Using the $CRED_{i,t}^{YoY}$ credibility measure. Countries: Brazil, Chile, Colombia, Guatemala, Mexico, Peru, and Turkey.

Figure A.14: Central Bank Credibility: $CRED_{i,t}^{1Q}$

Note: Dynamic response to a 10 percent commodity export price shock for different levels of central bank credibility. Using the $CRED_{i,t}^{1Q}$ credibility measure. Countries: Brazil, Chile, Colombia, Guatemala, Mexico, Peru, and Turkey.

Figure A.15: Central Bank Credibility: $CRED_{i,t}^{YoY}$, Extended Sample

Note: Dynamic response to a 10 percent commodity export price shock for different levels of central bank credibility. Using the $CRED_{i,t}^{YoY}$ credibility measure. Countries: Brazil, Chile, Colombia, Guatemala, Hungary, Indonesia, Mexico, Peru, Philippines, Poland, Romania, Thailand, and Turkey.

Figure A.16: Central Bank Credibility: $CRED_{i,t}^{1Q}$, Extended Sample

Note: Dynamic response to a 10 percent commodity export price shock for different levels of central bank credibility. Using the $CRED_{i,t}^{1Q}$ credibility measure. Countries: Brazil, Chile, Colombia, Guatemala, Hungary, Indonesia, Mexico, Peru, Philippines, Poland, Romania, Thailand, and Turkey.

Figure A.17: FXI and Central Bank Credibility: $FXI_{i,t}^{RA}$ and $CRED_{i,t}^{YoY}$

Note: Response to a 10 percent Commodity Export Price Shock. Using $FXI_{i,t}^{RA}$ and $CRED_{i,t}^{YoY}$ credibility measure. Countries: Brazil, Chile, Colombia, Guatemala, Hungary, Indonesia, Mexico, Peru, Philippines, Poland, Romania, Thailand, and Turkey.

Figure A.18: FXI and Central Bank Credibility: $FXI_{i,t}^{RA}$ and $CRED_{i,t}^{1Q}$

Note: Response to a 10 percent Commodity Export Price Shock. Using $FXI_{i,t}^{RA}$ and $CRED_{i,t}^{1Q}$ credibility measure. Countries: Brazil, Chile, Colombia, Guatemala, Hungary, Indonesia, Mexico, Peru, Philippines, Poland, Romania, Thailand, and Turkey.

Figure A.19: FXI and Central Bank Credibility: $FXI_{i,t}^{LYS}$ and $CRED_{i,t}^{1Q}$

Note: Response to a 10 percent Commodity Export Price Shock. Using $FXI_{i,t}^{LYS}$ and $CRED_{i,t}^{1Q}$ credibility measure. Countries: Brazil, Chile, Colombia, Guatemala, Hungary, Indonesia, Mexico, Peru, Philippines, Poland, Romania, Thailand, and Turkey.

Data

Table A.1: Countries and Summary Statistics

	IT Adoption Date	FXI^{RA}	FXI^{LYS}	$CRED^{YoY}$	$CRED^{EGap}$	$CRED^{LLR}$
Brazil	1999	-0.04	0.11	1.90	1.58	0.51
Chile	1999	0.18	3.90	0.22	0.12	0.91
Colombia	1999	0.25	3.37	0.18	0.33	0.85
Guatemala	2005	0.43	2.11	0.39	0.86	0.59
Hungary	2001	0.29	4.32	0.62	.	.
Indonesia	2005	0.26	4.24	1.50	.	.
Mexico	2001	0.14	3.89	0.83	0.74	0.68
Peru	2002	0.51	9.47	0.59	0.51	0.78
Philippines	2002	1.03	7.18	-0.28	.	.
Poland	1999	0.23	3.17	0.03	.	.
Romania	2005	0.19	4.65	0.59	.	.
Thailand	2000	1.09	9.86	0.36	.	.
Turkey	2006	0.29	3.72	2.70	1.79	0.32

Note: Column “IT Adoption Date” displays the year in which the inflation targeting framework was adopted in each country. The remaining columns show the average of the given variable for each country. All these are in percent, except for the column for $CRED^{LLR}$ which shows an index.

Table A.2: Variable Definitions and Data Sources

Variable Name	Definition	Source
FXI	FXI proxy, computed as the change of net reserves, normalized by the lagged monetary base . Net reserves are calculated as the difference between net foreign assets and central government deposits at the Central Bank.	See underlying variables' sources below.
NFA	Net foreign assets at the Central Bank.	IFS's Central Bank Survey: Net foreign assets series.
Gov. Deposits	Government deposits at the Central Bank.	IFS's Central Bank Survey: Liabilities to central government series.
NER	Nominal Exchange Rate. Domestic currency per U.S. Dollar.	IFS
Money Base	Monetary base.	IFS's Central Bank Survey.
CRED	Inflation gap from target, computed as the difference between the expected or realized CPI inflation rate (depending on the measure) and the Central Bank's target.	Inflation targets obtained from Central Bank's websites. Inflation expectations data obtained from surveys of inflation expectations conducted by central banks. See below for CPI.
CPI	Consumer price index.	IFS. FRED database for Chile.
CMX	Commodity export price index.	Gruss (2014)
MPR	Monetary policy-related interest rate. Percent per annum.	IFS. Central Bank website for Hungary, Peru, Poland, and Romania.
INV	Real gross fixed capital formation, seasonally adjusted using ARIMA X-12.	OECD' Quarterly National Accounts database. IFS for Guatemala, Indonesia, Peru, Philippines, Poland, Romania, Thailand, and Turkey.
GDP	Real gross domestic product, seasonally adjusted.	IFS. OECD's Quarterly National Accounts database for Colombia and Mexico.

B Chapter 2 Appendix

Aggregate Output, employment, and price dispersion

Note that equilibrium in the Home labor market requires

$$N_t = \int_0^1 N_t(j) dj = \int_0^1 \frac{Y_t(j)}{Z_t} dj = \frac{Y_t}{Z_t} \int_0^1 \left(\frac{P_{H,t}(j)}{P_{H,t}} \right)^{-\theta} dj \quad (\text{B.1})$$

Let

$$d_t = \int_0^1 \left(\frac{P_{H,t}(j)}{P_{H,t}} \right)^{-\theta} dj \quad (\text{B.2})$$

Then we get

$$N_t = \frac{Y_t}{Z_t} d_t \quad (\text{B.3})$$

Or equivalently

$$Y_t = \frac{Z_t}{d_t} N_t \quad (\text{B.4})$$

[Schmitt-Grohe et al. \(2007\)](#) show that $d_t \geq 1$ and it is equal to 1 only if all the prices are the same, that is, only if there is no price dispersion. Log-linearizing this we get

$$\hat{y}_t = \hat{n}_t + \hat{z}_t - \hat{d}_t \quad (\text{B.5})$$

where $\hat{d}_t$ is a measures of *price dispersion* within the Home economy. As pointed out before, the literature usually log-linearizes the equilibrium conditions around a zero inflation steady state. In that case it can easily be shown that $\hat{d}_t = 0$. However, when the economy exhibits trend inflation this measure is not necessarily zero and in fact evolves according to

$$\hat{d}_t = \theta \alpha \pi_H^{\theta-1} \left[\frac{\pi_H - 1}{1 - \alpha \pi_H^{\theta-1}} \right] \hat{\pi}_{H,t} + \alpha \pi_H^{\theta} \hat{d}_{t-1} \quad (\text{B.6})$$

As discussed in [Ascari and Sbordone \(2014\)](#) and [Ascari \(2004\)](#), price dispersion is akin to a negative aggregate productivity shock since it increases the amount of labor required to produce a given level of output, as can be seen in [\(B.4\)](#). In

the main text, the model assumed indivisible labor. This assumption makes price dispersion irrelevant for the dynamics of output and inflation, as noted by [Ascari and Sbordone \(2014\)](#). That is, when labor is not indivisible, i.e. when the Frisch elasticity is not zero, price dispersion enters the NKPC via its interaction with Frisch elasticity. This is not the case in our model. In a future iteration of the paper we will relax the invisible labor assumption.

Flexible Price Equilibrium and The Output Gap

The steady state level of output $\bar{Y}$ depends on steady state inflation π_H . Appendix [B](#) shows that in the steady state all inflation rates are the same. That is,

$$\bar{\pi} = \pi_H^* = \pi_H = \pi_F = \pi_F^* = \bar{\pi}^* \quad (\text{B.7})$$

Accordingly, we can say that the steady state level of output $\bar{Y}$ depends on steady state inflation $\pi_H = \bar{\pi}$. Let $\bar{Y}(\bar{\pi})$ denote the steady state level of output for a given level of trend inflation $\bar{\pi}$. Then, in general, let $\hat{y}_t$ be

$$\hat{y}_t = \log Y_t - \bar{Y}(\bar{\pi}) \quad (\text{B.8})$$

Define the output gap, $y_{gap,t}$, as the log-deviation of current output from the output that would arise in a flexible-price environment, namely the natural level of output Y_t^n . Indeed, the $y_{gap,t}$ is a measure of the nominal distortion implied by sticky prices.

$$y_{gap,t} = \log Y_t - \log Y_t^n \quad (\text{B.9})$$

No price rigidities implies $\alpha = 0$. From the above equations one can immediately see that when $\alpha = 0$ we get that $X_t = 1$ for all t . Furthermore, $d_t = 1$ as well. Now, the steady state output under flexible prices $\bar{Y}_{flex}$, becomes

$$\bar{Y}_{flex} = \frac{\theta - 1}{\theta} \frac{\mu \bar{Z}}{1 - \omega} \quad (\text{YFss})$$

and clearly $\bar{Y}_{flex}$ does not depend on trend inflation. As noted in [Ascari and Sbordone \(2014\)](#), this flexible price steady state is equal to the zero inflation steady state (ZISS). Therefore, $\bar{Y}_{flex}$ is also the steady state output under ZISS. That is, under zero inflation, i.e. $\bar{\pi} = 1$ we have that

$$\bar{Y}_{flex} = \bar{Y}(1) \quad (\text{B.10})$$

That is, the ZISS is equivalent to the flexible price steady state. Taking into account shocks the natural level of output is

$$Y_t^n = \frac{\theta - 1}{\theta} \frac{\mu}{(1 - \omega)} Z_t \quad (\text{B.11})$$

Taking ratios of Y_t^n and $\bar{Y}_{flex}$ we get

$$\frac{Y_t^n}{\bar{Y}_{flex}} = \frac{\frac{\theta-1}{\theta} \frac{\mu}{(1-\omega)} Z_t}{\frac{\theta-1}{\theta} \frac{\mu \bar{Z}}{1-\omega}} = \frac{Z_t}{\bar{Z}} \quad (\text{B.12})$$

Let $\hat{y}_t^n = \log Y_t^n - \log \bar{Y}_{flex}$ denote the log-deviations of the natural output level from its steady state. It follows that

$$\hat{y}_t^n = \log Y_t^n - \log \bar{Y}_{flex} = \log \frac{Z_t}{\bar{Z}} = \hat{z}_t \quad (\text{B.13})$$

The natural level of output deviates from its steady state level when there are productivity shocks. Hence, the output gap in a ZISS (i.e. when $\hat{\pi} = 1$) is

$$\begin{aligned} y_{gap,t} &= \log Y_t - Y_t^n \pm \log \bar{Y}_{flex} \\ &= \log Y_t - \log \bar{Y}_{flex} - Y_t^n + \log \bar{Y}_{flex} \\ &= \log Y_t - \log \bar{Y}(1) - Y_t^n + \log \bar{Y}_{flex} \\ &= \hat{y}_t - \log Y_t^n + \log \bar{Y}_{flex} \\ &= \hat{y}_t - (\log Y_t^n - \log \bar{Y}_{flex}) \\ &= \hat{y}_t - \hat{y}_t^n \\ &= \hat{y}_t - \hat{z}_t \end{aligned} \quad (\text{B.14})$$

Notice from (Yss) that when trend inflation is not zero and/or prices are not flexible, the steady state level of output will generally depend on the trend inflation level. In the general case, we can decompose $\hat{y}_t$ into

$$\begin{aligned}
\hat{y}_t &= \log Y_t - \bar{Y}(\bar{\pi}) \\
&= (\log Y_t - \log Y_t^n) + (\log Y_t^n - \log \bar{Y}_{flex}) + (\log \bar{Y}_{flex} - \log \bar{Y}(\bar{\pi})) \\
&= y_{gap,t} + \hat{y}_t^n - \tilde{y} \\
&= y_{gap,t} + \hat{z}_t - \tilde{y}
\end{aligned} \tag{B.15}$$

where we set $\tilde{y} = \log \bar{Y}(\bar{\pi}) - \log \bar{Y}_{flex}$, which is also equal to $\log \bar{Y}(\bar{\pi}) - \log \bar{Y}(1)$

As Ascari and Sbordone (2014) point out, $\tilde{Y}$ is the deviation of the level of output associated with steady state inflation $\bar{\pi}$ from the level of long-run output under flexible prices (or when steady state inflation is zero). Therefore, in general

$$\hat{y}_t = y_{gap,t} + \hat{z}_t - \tilde{y} \tag{B.16}$$

or alternatively

$$y_{gap,t} = \hat{y}_t - \hat{z}_t + \tilde{y} \tag{B.17}$$

We can further obtain an expression for $\tilde{y}$. Simply, take the ratio of (Yss) and (YFss)

$$\frac{\bar{Y}(\bar{\pi})}{\bar{Y}_{flex}} = \frac{\frac{\theta-1}{\theta} \frac{(1-\alpha\beta\pi_H^\theta)\mu\bar{Z}}{(1-\alpha\beta\pi_H^{\theta-1})(1-\omega)} \bar{X}}{\frac{\theta-1}{\theta} \frac{\mu\bar{Z}}{1-\omega}} = \frac{(1-\alpha\beta\pi_H^\theta)}{(1-\alpha\beta\pi_H^{\theta-1})} \left[\frac{1-\alpha\pi_H^{\theta-1}}{1-\alpha} \right]^{\frac{1}{1-\theta}} \tag{B.18}$$

then

$$\log \left(\frac{\bar{Y}(\bar{\pi})}{\bar{Y}_{flex}} \right) = \log \bar{Y}(\bar{\pi}) - \log \bar{Y}_{flex} = \log \left(\frac{1-\alpha\beta\pi_H^\theta}{1-\alpha\beta\pi_H^{\theta-1}} \right) + \frac{1}{1-\theta} \log \left(\frac{1-\alpha\pi_H^{\theta-1}}{1-\alpha} \right) \tag{B.19}$$

so

$$\tilde{y} = \log \left(\frac{1-\alpha\beta\pi_H^\theta}{1-\alpha\beta\pi_H^{\theta-1}} \right) + \frac{1}{1-\theta} \log \left(\frac{1-\alpha\pi_H^{\theta-1}}{1-\alpha} \right) \tag{B.20}$$

Clearly, under flexible prices (when $\alpha = 0$), or under a zero inflation steady state ($\bar{\pi}_H = 1$) it follows that $\tilde{y} = 0$.

Home and Foreign steady state inflation

The definition of CPI inflation is

$$\pi_t = \frac{P_t}{P_{t-1}} = \frac{(P_{H,t})^{1-\gamma}(P_{F,t})^\gamma}{(P_{H,t-1})^{1-\gamma}(P_{F,t-1})^\gamma} \quad (\text{B.21})$$

Therefore, in the steady state CPI is equal to

$$\bar{\pi} = (\pi_H)^{(1-\gamma)}(\pi_F)^\gamma \quad (\text{B.22})$$

Now, by definition import inflation is

$$\pi_{F,t} = \frac{P_{F,t}}{P_{F,t-1}} = \frac{\Xi_t P_{F,t}^* T_t}{\Xi_{t-1} P_{F,t-1}^* T_{t-1}} \quad (\text{B.23})$$

While the nominal exchange rate is non-stationary, changes in the nominal exchange rate are. Therefore, in the steady state, this collapses to:

$$\pi_F = \pi_F^* \quad (\text{B.24})$$

That is, in the steady state, the inflation rate of imports into the Home economy is simply the inflation rate of foreign producers. A similar argument for the inflation rate of imported goods into the Foreign economy implies that

$$\pi_H^* = \pi_H \quad (\text{B.25})$$

Now, the complete asset markets assumption implies that $\frac{\beta}{p^i} = \frac{\beta^*}{\pi^*}$. Which implies that in the steady state

$$\bar{\pi} = \bar{\pi}^* \quad (\text{B.26})$$

Therefore

$$(\pi_H)^{(1-\gamma)}(\pi_F)^\gamma = (\pi_F^*)^{(1-\gamma^*)}(\pi_H^*)^{\gamma^*} \quad (\text{B.27})$$

Using eqs. (B.24) and (B.25) in the RHS of eq. (B.27) we have that

$$(\pi_F^*)^{(1-\gamma^*)}(\pi_H^*)^{\gamma^*} = (\pi_F)^{(1-\gamma^*)}(\pi_H)^{\gamma^*} \quad (\text{B.28})$$

Setting the RHS of eq. (B.28) and the LHS of eq. (B.27) equal to each other we get

$$\pi_H^{(1-\gamma-\gamma^*)} = \pi_F^{(1-\gamma-\gamma^*)} \quad (\text{B.29})$$

which immediately implies that

$$\pi_H = \pi_F \quad (\text{B.30})$$

Which means that

$$\pi_H^* = \pi_H = \pi_F = \pi_F^* \quad (\text{B.31})$$

Finally, we have that

$$\bar{\pi} = (\pi_H)^{(1-\gamma)}(\pi_F)^\gamma = (\pi_H)^{(1-\gamma)}(\pi_H)^\gamma = \pi_H \quad (\text{B.32})$$

All of the above implies that

$$\bar{\pi} = \pi_H^* = \pi_H = \pi_F = \pi_F^* = \bar{\pi}^* \quad (\text{B.33})$$

That is, in the steady state, all inflation rates are the same.

The Complete Linearized Model

Tables (B.1) and (B.2) list all endogenous and exogenous variables in the linear model, respectively, and give their descriptions. There are 38 endogenous variables:

Home Economy: $y_{gap,t}$, $\hat{i}_t$, $\hat{\pi}_{H,t}$, $\hat{z}_t$, $\hat{\psi}_t$, $\hat{y}_t^n$, $\hat{y}_t$, $\hat{s}_t$, $\hat{\tau}_t$, $\hat{\pi}_t$, $\hat{\xi}_t$, $\hat{q}_t$, $\hat{n}_t$, $\hat{d}_t$, $\hat{w}_t$, $\hat{c}_t$, $\hat{c}_{H,t}$, $\hat{c}_{F,t}$, $\hat{r}_t$, $\hat{\nu}_t$

Foreign Economy: $y_{gap,t}^*$, $\hat{i}_t^*$, $\hat{\pi}_{F,t}^*$, $\hat{z}_t^*$, $\hat{\psi}_t^*$, $\hat{y}_t^{*n}$, $\hat{y}_t^*$, $\hat{s}_t^*$, $\hat{\tau}_t^*$, $\hat{\pi}_t^*$, $\hat{n}_t^*$, $\hat{d}_t^*$, $\hat{w}_t^*$, $\hat{c}_t^*$, $\hat{c}_{F,t}^*$, $\hat{c}_{H,t}^*$, $\hat{r}_t^*$, $\hat{\nu}_t^*$

6 Exogenous variables: ε_t^z , $\varepsilon_t^{z^*}$, ε_t^τ , $\varepsilon_t^{\tau^*}$, ε_t^ν , $\varepsilon_t^{\nu^*}$

Parameters: β , α , θ , $\bar{\pi} = \pi_H$, $\bar{\pi}^* = \pi_F^*$, γ , γ^* , ρ_i , ρ_{i^*} , ρ_ν , ρ_{ν^*} , ρ_z , ρ_{z^*} , ρ_τ , ρ_{τ^*}

Constant: $\tilde{y}$, $\tilde{y}^*$

Table B.1: Endogenous Variables

<i>Home</i>	<i>Foreign</i>	<i>Description</i>
$y_{gap,t}$	$y_{gap,t}^*$	Output Gap
$\hat{y}_t$	$\hat{y}_t^*$	Output
$\hat{y}_t^n$	$\hat{y}_t^{*n}$	Natural Output
$\hat{\pi}_t$	$\hat{\pi}_t^*$	CPI Inflation
$\hat{\pi}_{H,t}$	$\hat{\pi}_{F,t}^*$	Domestic Inflation
$\hat{\psi}_t$	$\hat{\psi}_t^*$	NKPC Aux variable
$\hat{s}_t$	$\hat{s}_t^*$	Terms of Trade
$\hat{n}_t$	$\hat{n}_t^*$	Employment
$\hat{d}_t$	$\hat{d}_t^*$	Domestic Price Dispersion
$\hat{c}_t$	$\hat{c}_t^*$	Consumption
$\hat{c}_{H,t}$	$\hat{c}_{H,t}^*$	Consumption of Home-produced goods
$\hat{c}_{F,t}$	$\hat{c}_{F,t}^*$	Consumption of Foreign-produced goods
$\hat{w}_t$	$\hat{w}_t^*$	Real Wage Rate
$\hat{r}_t$	$\hat{r}_t^*$	Real Interest Rate
$\hat{i}_t$	$\hat{i}_t^*$	Nominal Interest Rate
$\hat{z}_t$	$\hat{z}_t^*$	AR(1) Technology shock process
$\hat{\nu}_t$	$\hat{\nu}_t^*$	AR(1) Monetary Policy shock process
$\hat{\tau}_t$	$\hat{\tau}_t^*$	AR(1) Trade shock process
$\hat{\xi}_t$		Nominal Exchange Rate
$\hat{q}_t$		Real Exchange Rate

Table B.2: Exogenous Variables

<i>Home</i>	<i>Foreign</i>	<i>Description</i>
ε_t^z	ε_t^{z*}	Technology shock
ε_t^τ	$\varepsilon_t^{\tau*}$	Trade costs shock
ε_t^ν	$\varepsilon_t^{\nu*}$	Monetary policy shock

$$y_{gap,t} = E_t[y_{gap,t+1}] - (\hat{i}_t - E_t[\hat{\pi}_{H,t+1}]) + E_t[\Delta \hat{z}_{t+1}] \quad (\text{IS})$$

$$y_{gap,t}^* = E_t[y_{gap,t+1}^*] - (\hat{i}_t^* - E_t[\hat{\pi}_{F,t+1}^*]) + E_t[\Delta \hat{z}_{t+1}^*] \quad (\text{IS}^*)$$

$$\hat{\pi}_{H,t} = \eta_1(y_{gap,t} - \tilde{y}) + \eta_2 E_t[\hat{\pi}_{H,t+1}] + \eta_3 E_t[\hat{\psi}_{t+1}] \quad (\text{B.34})$$

$$\hat{\psi}_t = (1 - \alpha\beta\pi_H^\theta)(y_{gap,t} - \tilde{y}) + (\alpha\beta\pi_H^\theta) \left[\theta E_t[\hat{\pi}_{H,t+1}] + E_t[\hat{\psi}_{t+1}] \right] \quad (\text{B.35})$$

with η_1 , η_2 , and η_3 defined as

$$\begin{aligned} \eta_1 &= \frac{(1 - \alpha\beta\pi_H^\theta)(1 - \alpha\pi_H^{\theta-1})}{\alpha\pi_H^{\theta-1}} \\ \eta_2 &= \beta [1 + \theta(\pi_H - 1)(1 - \alpha\pi_H^{\theta-1})] \\ \eta_3 &= \beta(\pi_H - 1)(1 - \alpha\pi_H^{\theta-1}) \end{aligned} \quad (\text{B.36})$$

and

$$\tilde{y} = \log \left(\frac{1 - \alpha\beta\pi_H^\theta}{1 - \alpha\beta\pi_H^{\theta-1}} \right) + \frac{1}{1 - \theta} \log \left(\frac{1 - \alpha\pi_H^{\theta-1}}{1 - \alpha} \right) \quad (\text{B.37})$$

$$\hat{\pi}_{F,t}^* = \eta_1^*(y_{gap,t}^* - \tilde{y}^*) + \eta_2^* E_t[\hat{\pi}_{F,t+1}^*] + \eta_3^* E_t[\hat{\psi}_{t+1}^*] \quad (\text{B.38})$$

$$\hat{\psi}_t^* = (1 - \alpha\beta(\pi_F^*)^\theta)(y_{gap,t}^* - \tilde{y}^*) + (\alpha\beta(\pi_F^*)^\theta) \left[\theta E_t[\hat{\pi}_{F,t+1}^*] + E_t[\hat{\psi}_{t+1}^*] \right] \quad (\text{B.39})$$

and where η_1^* , η_2^* , and η_3^* are defined as

$$\begin{aligned} \eta_1^* &= \frac{(1 - \alpha\beta(\pi_F^*)^\theta)(1 - \alpha(\pi_F^*)^{\theta-1})}{\alpha(\pi_F^*)^{\theta-1}} \\ \eta_2^* &= \beta [1 + \theta(\pi_F^* - 1)(1 - \alpha(\pi_F^*)^{\theta-1})] \\ \eta_3^* &= \beta(\pi_F^* - 1)(1 - \alpha(\pi_F^*)^{\theta-1}) \end{aligned} \quad (\text{B.40})$$

and

$$\tilde{y}^* = \log \left(\frac{1 - \alpha\beta(\pi_F^*)^\theta}{1 - \alpha\beta(\pi_F^*)^{\theta-1}} \right) + \frac{1}{1 - \theta} \log \left(\frac{1 - \alpha(\pi_F^*)^{\theta-1}}{1 - \alpha} \right) \quad (\text{B.41})$$

$$\hat{y}_t^n = \hat{z}_t \quad \hat{y}_t^{*n} = \hat{z}_t^* \quad (\text{YNAT})$$

$$y_{gap,t} = \hat{y}_t - \hat{z}_t + \tilde{y} \quad y_{gap,t}^* = \hat{y}_t^* - \hat{z}_t^* + \tilde{y}^* \quad (\text{YGAP})$$

$$\hat{y}_t = \hat{y}_t^* + \hat{s}_t - \hat{\tau}_t \quad \hat{y}_t^* = \hat{y}_t + \hat{s}_t^* - \hat{\tau}_t^* \quad (\text{B.42})$$

$$\hat{\pi}_t = \hat{\pi}_{H,t} + \gamma \Delta \hat{s}_t \quad \hat{\pi}_t^* = \hat{\pi}_{F,t}^* + \gamma^* \Delta \hat{s}_t^* \quad (\text{B.43})$$

$$\Delta \hat{s}_t = \hat{\pi}_{F,t}^* - \hat{\pi}_{H,t} + \Delta \hat{\tau}_t + \Delta \xi_t \quad (\text{B.44})$$

$$\hat{q}_t = (1 - \gamma - \gamma^*)\hat{s}_t + \gamma^*\hat{\tau}_t^* - (1 - \gamma^*)\hat{\tau}_t \quad (\text{B.45})$$

$$\hat{y}_t = \hat{n}_t + \hat{z}_t - \hat{d}_t \quad \hat{y}_t^* = \hat{n}_t^* + \hat{z}_t^* - \hat{d}_t^* \quad (\text{B.46})$$

$$\hat{d}_t = \theta\alpha\pi_H^{\theta-1} \left[\frac{\pi_H - 1}{1 - \alpha\pi_H^{\theta-1}} \right] \hat{\pi}_{H,t} + \alpha\pi_H^\theta \hat{d}_{t-1} \quad (\text{B.47})$$

$$\hat{d}_t^* = \theta\alpha(\pi_F^*)^{\theta-1} \left[\frac{\pi_F^* - 1}{1 - \alpha(\pi_F^*)^{\theta-1}} \right] \hat{\pi}_{F,t}^* + \alpha(\pi_F^*)^\theta \hat{d}_{t-1}^* \quad (\text{B.48})$$

$$\hat{y}_t = \hat{c}_t + \gamma\hat{s}_t \quad \hat{y}_t^* = \hat{c}_t^* + \gamma^*\hat{s}_t^* \quad (\text{B.49})$$

$$\hat{w}_t = \hat{c}_t \quad \hat{w}_t^* = \hat{c}_t^* \quad (\text{B.50})$$

$$\hat{c}_{H,t} = \hat{c}_t + \gamma\hat{s}_t \quad \hat{c}_{F,t} = \hat{c}_t - (1 - \gamma)\hat{s}_t \quad (\text{B.51})$$

$$\hat{c}_{F,t}^* = \hat{c}_t^* + \gamma^*\hat{s}_t^* \quad \hat{c}_{H,t}^* = \hat{c}_t^* - (1 - \gamma^*)\hat{s}_t^* \quad (\text{B.52})$$

$$\hat{r}_t = \hat{i}_t - E_t[\hat{\pi}_{H,t+1}] \quad \hat{r}_t^* = \hat{i}_t^* - E_t[\hat{\pi}_{F,t+1}^*] \quad (\text{B.53})$$

$$\hat{i}_t = \rho_i \hat{i}_{t-1} + (1 - \rho_i)(\phi_\pi \hat{\pi}_{H,t} + \phi_y \hat{y}_t) + \nu_t \quad (\text{B.54})$$

$$\hat{i}_t^* = \rho_{i^*} \hat{i}_{t-1}^* + (1 - \rho_{i^*})(\phi_{\pi^*} \hat{\pi}_{F,t}^* + \phi_{y^*} \hat{y}_t^*) + \nu_t^* \quad (\text{B.55})$$

$$z_t = \rho_z z_{t-1} + \varepsilon_t^z \quad z_t^* = \rho_{z^*} z_{t-1}^* + \varepsilon_t^{z^*} \quad (\text{B.56})$$

$$\tau_t = \rho_\tau \tau_{t-1} + \varepsilon_t^\tau \quad \tau_t^* = \rho_{\tau^*} \tau_{t-1}^* + \varepsilon_t^{\tau^*} \quad (\text{B.57})$$

$$\nu_t = \rho_\nu \nu_{t-1} + \varepsilon_t^\nu \quad \nu_t^* = \rho_{\nu^*} \nu_{t-1}^* + \varepsilon_t^{\nu^*} \quad (\text{B.58})$$

The Complete Non-linear Model

36 Endogenous variables:

Home Economy: $C_t, C_{H,t}, C_{F,t}, \pi_t, \pi_{H,t}, X_t, \psi_t, \phi_t, MC_t, Y_t, w_t, N_t, d_t, i_t, S_t, Q_t, \Xi_t, Z_t, T_t$

Foreign Economy: $C_t^*, C_{F,t}^*, C_{H,t}^*, \pi_t^*, \pi_{F,t}^*, X_t^*, \psi_t^*, \phi_t^*, MC_t^*, Y_t^*, w_t^*, N_t^*, d_t^*, i_t^*, S_t^*, Z_t^*, T_t^*$

6 Exogenous variables: $\varepsilon_t^z, \varepsilon_t^{z^*}, \varepsilon_t^\tau, \varepsilon_t^{\tau^*}, \varepsilon_t^\nu, \varepsilon_t^{\nu^*}$

Parameters: $\beta, \alpha, \theta, \bar{\pi} = \pi_H, \bar{\pi}^* = \pi_F^*, \gamma, \gamma^*, \mu, \mu^*, \omega, \omega^*$

$$\frac{1}{(1+i_t)} = \beta E_t \left[\frac{C_t}{C_{t+1}\pi_{t+1}} \right] \quad \frac{1}{(1+i_t^*)} = \beta E_t \left[\frac{C_t^*}{C_{t+1}^*\pi_{t+1}^*} \right] \quad (\text{Euler})$$

$$1 = \alpha \pi_{H,t}^{\theta-1} + (1-\alpha) X_t^{1-\theta} \quad 1 = \alpha (\pi_{F,t}^*)^{\theta-1} + (1-\alpha) (X_t^*)^{1-\theta} \quad (\text{APD})$$

$$X_t = \frac{\tilde{P}_{H,t}}{P_{H,t}} = \left(\frac{\theta}{\theta-1} \right) \frac{\psi_t}{\phi_t} \quad X_t^* = \frac{\tilde{P}_{F,t}^*}{P_{F,t}^*} = \left(\frac{\theta}{\theta-1} \right) \frac{\psi_t^*}{\phi_t^*} \quad (\text{OP})$$

$$\psi_t = MC_t + (\alpha\beta) E_t [\pi_{H,t+1}^\theta \psi_{t+1}] \quad \psi_t^* = MC_t^* + (\alpha\beta) E_t [(\pi_{F,t+1}^*)^\theta \psi_{t+1}^*] \quad (\text{PSI})$$

$$\phi_t = 1 + (\alpha\beta) E_t [\pi_{H,t+1}^{\theta-1} \phi_{t+1}] \quad \phi_t^* = 1 + (\alpha\beta) E_t [(\pi_{F,t+1}^*)^{\theta-1} \phi_{t+1}^*] \quad (\text{PHI})$$

$$MC_t = \frac{(1-\omega)}{\mu} \frac{Y_t}{Z_t} \quad MC_t^* = \frac{(1-\omega^*)}{\mu^*} \frac{Y_t^*}{Z_t^*} \quad (\text{MC})$$

$$w_t = \frac{W_t}{P_t} = C_t \quad w_t^* = \frac{W_t^*}{P_t^*} = C_t^* \quad (\text{RW})$$

$$N_t = \frac{Y_t}{Z_t} d_t \quad N_t^* = \frac{Y_t^*}{Z_t^*} d_t^* \quad (\text{LO})$$

$$d_t = (1-\alpha) X_t^{-\theta} + \alpha \pi_{H,t}^\theta d_{t-1} \quad d_t^* = (1-\alpha) (X_t^*)^{-\theta} + \alpha (\pi_{F,t}^*)^\theta d_{t-1}^* \quad (\text{PD})$$

$$Y_t = C_t S_t^\gamma \mu \quad Y_t^* = C_t^* (S_t^*)^{\gamma^*} \mu_t^* \quad (\text{MKT})$$

$$\pi_t = \pi_{H,t} \left(\frac{S_t}{S_{t-1}} \right)^\gamma \quad \pi_t^* = \pi_{F,t}^* \left(\frac{S_t^*}{S_{t-1}^*} \right)^{\gamma^*} \quad (\text{CPITOT})$$

$$Y_t = Y_t^* \frac{S_t}{T_t} \frac{\mu}{\mu^*} \quad (\text{YY})$$

$$C_t = C_t^* Q_t \quad (\text{RS})$$

$$C_{H,t} = (1-\gamma) S_t^\gamma C_t \quad C_{F,t} = \gamma \frac{C_t}{S_t^{1-\gamma}} \quad (\text{CHCF})$$

$$C_{F,t}^* = (1-\gamma^*) (S_t^*)^{\gamma^*} C_t^* \quad C_{H,t}^* = \gamma^* \frac{C_t^*}{(S_t^*)^{(1-\gamma^*)}} \quad (\text{CHCFstar})$$

$$Q_t = (S_t)^{(1-\gamma-\gamma^*)} \frac{(T_t^*)^{\gamma^*}}{(T_t)^{(1-\gamma^*)}} \quad (\text{RER})$$

$$E_t \left[\beta \frac{C_t}{C_{t+1}\pi_{t+1}} (1+i_t) \right] = E_t \left[\beta \frac{C_t}{C_{t+1}\pi_{t+1}} (1+i_t^*) (\Xi_{t+1}/\Xi_t) \right] \quad (\text{UIRP})$$

$$\left(\frac{1+i_t}{1+\bar{i}} \right) = \left(\frac{\pi_t}{\bar{\pi}} \right)^{\phi_\pi} \left(\frac{Y_t}{\bar{Y}} \right)^{\phi_y} e^{\nu_t} \quad \left(\frac{1+i_t^*}{1+\bar{i}^*} \right) = \left(\frac{\pi_t^*}{\bar{\pi}^*} \right)^{\phi_\pi^*} \left(\frac{Y_t^*}{\bar{Y}^*} \right)^{\phi_y^*} e^{\nu_t^*} \quad (\text{B.59})$$

$$z_t = \rho_z z_{t-1} + \varepsilon_t^z \quad (\text{B.60})$$

$$z_t^* = \rho_{z^*} z_{t-1}^* + \varepsilon_t^{z^*} \quad (\text{B.61})$$

$$\tau_t = \rho_\tau \tau_{t-1} + \varepsilon_t^\tau \quad (\text{B.62})$$

$$\tau_t^* = \rho_{\tau^*} \tau_{t-1}^* + \varepsilon_t^{\tau^*} \quad (\text{B.63})$$

$$\nu_t = \rho_\nu \nu_{t-1} + \varepsilon_t^\nu \quad (\text{B.64})$$

$$\nu_t^* = \rho_{\nu^*} \nu_{t-1}^* + \varepsilon_t^{\nu^*} \quad (\text{B.65})$$

The Steady State

Assume that in the steady state $\bar{T} = \bar{T}^*$, and $\bar{Z} = \bar{Z}^*$. Given the fundamental parameters, the steady state is solved in this sequence

$$\frac{\bar{\pi}}{\beta} = 1 + i \quad \frac{\bar{\pi}^*}{\beta} = 1 + i^* \quad (\text{Eulerss})$$

$$\bar{X} = \left[\frac{1 - \alpha \pi_H^{\theta-1}}{1 - \alpha} \right]^{\frac{1}{1-\theta}} \quad \bar{X}^* = \left[\frac{1 - \alpha (\pi_F^*)^{\theta-1}}{1 - \alpha} \right]^{\frac{1}{1-\theta}} \quad (\text{OPss})$$

$$\bar{d} = \frac{1 - \alpha}{1 - \alpha \pi_H^\theta} \bar{X}^\theta \quad \bar{d}^* = \frac{1 - \alpha}{1 - \alpha (\pi_F^*)^\theta} (\bar{X}^*)^\theta \quad (\text{PDss})$$

$$\bar{Y} = \frac{\theta - 1}{\theta} \frac{(1 - \alpha \beta \pi_H^\theta) \mu \bar{Z}}{(1 - \alpha \beta \pi_H^{\theta-1})(1 - \omega)} \bar{X} \quad \bar{Y}^* = \frac{\theta - 1}{\theta} \frac{(1 - \alpha \beta (\pi_F^*)^\theta) \mu^* \bar{Z}^*}{(1 - \alpha \beta (\pi_F^*)^{\theta-1})(1 - \omega)} \bar{X}^* \quad (\text{Yss})$$

$$\bar{N} = \frac{\bar{Y}}{\bar{Z}} \bar{d} \quad \bar{N}^* = \frac{\bar{Y}^*}{\bar{Z}^*} \bar{d}^* \quad (\text{Nss})$$

$$\bar{C} = \frac{\bar{Y}}{(\bar{T})^{\gamma\mu}} \quad \bar{C}^* = \frac{\bar{Y}^*}{(\bar{T}^*)^{\gamma^*\mu^*}} \quad (\text{Css})$$

$$\tilde{w} = \bar{C} \quad \tilde{w}^* = \bar{C}^* \quad (\text{wss})$$

$$\bar{\phi} = \frac{1}{1 - \alpha \beta \pi_H^{\theta-1}} \quad \bar{\phi}^* = \frac{1}{1 - \alpha \beta (\pi_F^*)^{\theta-1}} \quad (\text{PHIss})$$

$$\bar{\psi} = \frac{(1 - \omega) \bar{Y}}{(1 - \alpha \beta \pi_H^\theta) \mu \bar{Z}} \quad \bar{\psi}^* = \frac{(1 - \omega^*) \bar{Y}^*}{(1 - \alpha \beta (\pi_F^*)^\theta) \mu^* \bar{Z}^*} \quad (\text{PSIss})$$

$$\bar{S} = \bar{T} \quad \bar{S}^* = \bar{T}^* \quad (\text{Sss})$$

$$\bar{C}_H = (1 - \gamma)\bar{S}^\gamma\bar{C} \qquad \bar{C}_F = \gamma\frac{\bar{C}}{\bar{S}^{1-\gamma}} \qquad (\text{CHCF}_{\text{ss}})$$

$$\bar{C}_F^* = (1 - \gamma^*)(\bar{S}^*)^{\gamma^*}\bar{C}^* \qquad \bar{C}_H^* = \gamma^*\frac{\bar{C}^*}{(\bar{S}^*)^{(1-\gamma^*)}} \qquad (\text{CHCF}_{\text{starss}})$$

$$\bar{Q} = \bar{T}^{(\gamma^*-\gamma)} \qquad (\text{Q}_{\text{ss}})$$

$$\bar{C} = \bar{C}^*\bar{Q} \qquad (\text{RS}_{\text{ss}})$$

$$\frac{\bar{Y}}{\bar{Y}^*} = \frac{(1 - \gamma + \gamma^*)\bar{Z}}{(1 - \gamma^* + \gamma)\bar{Z}^*} \qquad (\text{B.66})$$

More Impulse Response Functions

Figure B.1: Impulse Response Functions: Trade Costs Shock in the Home Economy, Home Response

Note: Dynamic response of Home variables to a 1 percent trade costs shock, under different inflation targets.

Figure B.2: Impulse Response Functions: Trade Costs Shock in the Home Economy, Foreign Response

Note: Dynamic response of Foreign variables to a 1 percent trade costs shock, under different inflation targets.

Parametrization

The following parametrization was used to conduct all simulations of the model, unless noted otherwise in the main text. The Foreign equivalent of each parameter takes the same values as those listed here, unless noted otherwise in the main text.

Table B.3: Parameterization

<i>Parameter</i>	<i>Value</i>	<i>Description</i>
γ	0.4	Openness
α	0.75	Calvo parameter
β	0.99	Discount factor
θ	9	Elasticity of substitution
π_H	0, 2, 4	Trend inflation at Home
π_F	0, 2, 4	Trend inflation at Foreign
ϕ_π	1.5	Inflation feedback Taylor Rule
ϕ_y	0.5/4	Output feedback Taylor Rule
ρ_i	0.8	Inertia in Taylor Rule
ρ_τ	0.95	Persistence trade costs shock
ρ_z	0.9	Persistence technology shock
ρ_ν	0	Persistence monetary policy shock

VITA

RENZO MANUEL ALVAREZ OYOLA

2013	B.A. Economics Florida International University Miami, FL
2013	B.S. Mathematics Florida International University Miami, FL
2013	B.A. Philosophy Florida International University Miami, FL
2015	M.A. Economics Florida International University Miami, FL
2017	Ph.D. Intern International Monetary Fund Washington, DC
2013–2018	Teaching Assistant Florida International University Miami, FL
2015–2019	Doctoral Candidate Florida International University Miami, FL
2018–2019	Dissertation Year Fellowship Florida International University Miami, FL

PUBLICATIONS AND PRESENTATIONS

Alvarez, R., Shoja, A., Uddin, S., & Yilmazkuday, H. (2019). *Daily exchange rate pass-through into micro prices*. Applied Economics Letters, 26(6), 440–445.