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Measuring Central Bank Credibility From the Effect of Inflation Shocks on Asset Prices

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MEASURING CENTRAL BANK CREDIBILITY FROM THE EFFECT OF

INFLATION SHOCKS ON ASSET PRICES

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JUNMEI XU

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MEASURING CENTRAL BANK CREDIBILITY FROM THE EFFECT OF

INFLATION SHOCKS ON ASSET PRICES

This thesis is approved as a creditable and independent investigation by a

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conclusions reached by the candidate are necessarily the conclusions of the major

department.

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ABSTRACT

MEASURING CENTRAL BANK CREDIBILITY FROM THE EFFECT OF

INFLATION SHOCKS ON ASSET PRICES

JUNMEI XU

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In the early 1990s, the Bank of Canada explicitly adopted the inflation-targeting framework for monetary policy, while the Federal Reserve did not; instead, the Fed settled on an implicit inflation-targeting framework. In this study, I test whether the Bank of Canada and the Federal Reserve earned credibility for their respective commitments—explicit or otherwise—to maintain low and stable inflation. I model how credibility shapes the responses of asset prices to inflation shocks. And, for each country, I estimate responses of commodity and foreign exchange prices to announcements of inflation shocks during the periods of 1982 to 1991 (pre-inflation targeting period) and 1996 to 2005 (inflation-targeting period). I conclude that for Canada in the period 1996 to 2005, but not before, the Bank of Canada's commitment to maintain low and stable inflation was credible. For the US, the credibility of the Federal Reserve seems to have grown as well, though to a lesser extent relative to the Bank of Canada. Taken together, my results indicate that the Bank of Canada in the period1996 to 2005 is most credible, both relative to its own past and to the Federal Reserve.

CHAPTER 1: INTRODUCTION

Over the past two decades (1990-2010), inflation targeting as a framework for monetary policy has been widely adopted by central banks. The framework plays an increasingly important role in the development of monetary policy throughout the world. In an inflation-targeting framework, a central bank announces official numerical targets or target ranges for the inflation rate over one or more time horizons and specifies that achieving a low and stable inflation rate is the primary long-run goal of monetary policy. By establishing numerical objectives to be met over a specified period, the inflation-targeting framework holds central bankers accountable and, thus, encourages frequent communication between inflation-targeting central banks and the public. Additionally, frequent communication increases the transparency of monetary policy. The explicit numerical objectives and the transparency of inflation targeting policy together make monitoring inflation targeting easier for the public and help the inflation targeting central banks build credibility.

In this study, I test and compare central bank credibility for low and stable inflation of two central banks—namely, the Bank of Canada and the Federal Reserve System over the period of 1980 to 2005. In the early 1990s, the Bank of Canada publicly transitioned adopted in inflation-targeting framework for monetary policy; meanwhile, the Federal Reserve did not. This change at the Bank of Canada relative to itself and the Federal Reserve allows me to evaluate the effects of different monetary policies on central bank credibility for low and stable inflation.

Central bank credibility has become a focal point in the contemporary literature on monetary policy, where credibility is commonly defined as the ability of the central bank to manage inflation expectations of economic agents. Specifically, if a central bank were to achieve credibility, economic agents would be less likely to adjust their expectations of inflation upward in response to a one-off inflation shock. Put differently, inflation expectations would be anchored. In contrast, if a central bank were not to achieve credibility, economic agents would instead interpret an inflation shock as a new, looser monetary policy. In this case, economic agents would raise their expectations of inflation and thereby bring about a higher inflation rate. For example, during the 1970s, the Federal Reserve increased the federal funds rate in order to reduce inflation. However, because it did not have credibility for maintaining low and stable inflation at that time, the federal funds rate increases in fact led to higher inflation expectations, because market participants deduced that an expansionary monetary policy was likely to occur in the near future and the Federal Reserve would not maintain its inflation target. (C. D. Romer & Romer, 2000)

In general, the greater central bank credibility is, the more convinced economic agents are that the announced inflation target will be met and, thus, the more firmly anchored inflation expectations are. When a central bank adopts an inflation-targeting framework for monetary policy, it does so, in part, to build credibility. If a central bank is credible, aggregate shocks exert their impact transitorily, and thus the central bank anchors inflation expectations and achieves its inflation target. This is why increasing central bank credibility is one of the objectives of inflation targeting policy.

In the literature there are several studies that use the dynamics of long-term inflation expectations to infer something about central bank credibility. In some of these studies, researchers use survey data to measure inflation expectations directly; in others, researchers use financial market data to infer the dynamics of inflation expectations indirectly. In this study, I examine commodity-market data. Specifically, I measure the responses of commodity prices to inflation shocks in order to identify whether inflation expectations are relatively well anchored in Canada (where the Bank of Canada explicitly targets inflation) and the United States (where the Federal Reserve does not explicitly target inflation). Here, I identify the inflation shock as a supply shock that forces the central bank to choose between inflation stability and output stability. If a central bank (e.g. the Bank of Canada) adopts an explicit inflation-targeting framework, then when inflation shocks occur, the central bank chooses to minimize inflation variability (at the cost of output variability); in this case, inflation expectations will be anchored. However, if the central bank (e.g. the Federal Reserve) does not adopt an explicit inflation-targeting framework, the central bank could more easily choose to minimize output variability (at the cost of inflation variability); in this case, inflation expectations will not be anchored.

Because commodity prices are relatively flexible, I use them as an indicator of the commodity market's perception of central bank credibility. Unlike most goods prices, which are sticky in the short run and can only reflect looseness or tightness of monetary policy in the long run, commodity prices adjust immediately in response to aggregate shocks. And, importantly, commodity prices respond differently according to whether or not the market perceives the central bank as a credible inflation fighter. Therefore, the response of commodity prices to inflation shocks can be used to determine whether

inflation expectations are anchored or not; anchored expectations reflect central bank credibility.

In summary, in this thesis, I estimate central bank credibility under alternative monetary policy frameworks: namely, inflation targeting and non-inflation targeting. I focus on Canada, which adopted an explicit IT framework, and the U.S., which did not (during my sample period). In February 1991, the Bank of Canada announced its inflation target, aiming to reduce the inflation from the 5 to 6 percent level to around a 2 percent level by 1995. Before that, by the fourth quarter of 1990, the inflation rate had reached 4.2 percent from a high of 5.5 percent in early 1989 (Figure 1). In addition, the Canadian economy was in recession in 1990, when inflation pressures lessened somewhat. By 1993, inflation actually undershot the target range and maintained the level below or close to 2 percent since then, as shown in Figure 1 (Bernanke et al., 1999).

Figure 1: Unemployment, inflation and interest rates in Canada, 1972-2005
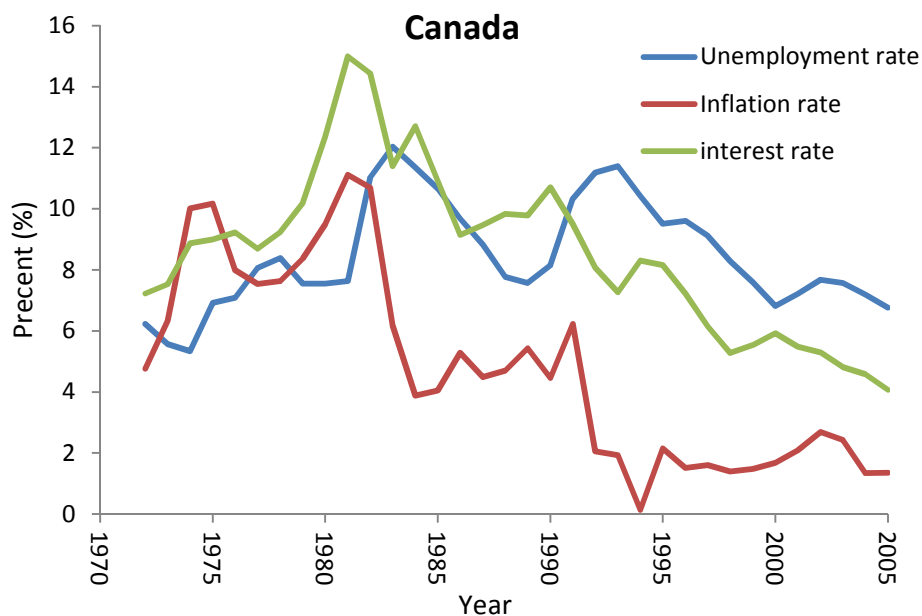
Source: OECD main economic indicators

Meanwhile, the Federal Reserve did not adopt an inflation-targeting framework, at least not explicitly. Rather, the monetary policy of the Federal Reserve was informed by a dual mandate to maintain both high employment and low and stable inflation. In the event, in the 1990s, inflation in the US was around 3 percent (Figure 2), slightly higher than that in Canada. And, the unemployment rate peaked at around 7.6 percent in 1992 and then dropped to below 6 percent after 1994 (Figure 2), which was much lower than that in Canada at that time. By 1998, the unemployment rate in the US was approximately half of that in Canada (Goodfiriend, 2005).

Figure 2: Unemployment, inflation and interest rates in the U.S., 1972-2005
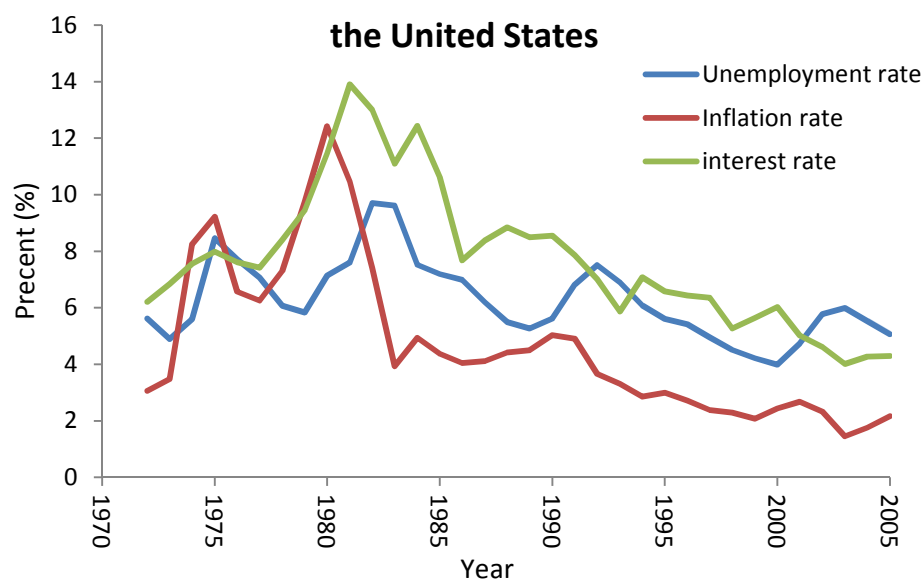
Source: OECD main economic indicators

In summary, because of its explicit adoption of an inflation-targeting framework, the Bank of Canada announced numerical targets for inflation and adopted a more transparent policy that, to this day, entails fairly detailed communication with the public.

Thus, I hypothesize that the Bank of Canada is credibly committed to its inflation target. In contrast, the monetary policy for the United States was not transparent and communication between the Federal Reserve and the public was relatively poor. Since the 1990s, the Fed seems to have settled on an implicit inflation-targeting framework for its monetary policy. Presumably, because the framework is implicit, it lacks transparency and is less communicative than the Canadian framework. Thus, I estimate whether the explicit adoption of an inflation-targeting framework afforded the Bank of Canada credibility, and whether the Federal Reserve lacks such credibility.

The working hypothesis of this study is that the central bank that adopted an explicit inflation-targeting framework achieved a relatively high degree of credibility both relative to its own past and to the comparable central bank that did not adopt an explicit inflation-targeting framework. Specifically, my working hypothesis is that the Bank of Canada is, in the inflation-targeting period, the more credible of the two central banks. To test this working hypothesis I pursue four objectives. The first objective is to demonstrate how changes of commodity prices reflect the market's expectations of inflation. To achieve the first objective, I explore a relationship between commodity prices and interest rates. This relationship reveals how real commodity prices respond to changes in interest. The second objective is to demonstrate how credible and non-credible central banks adjust the policy instrument (interest rate) in response to inflation shocks. To achieve the second objective, I specify a macroeconomic model in which central-bank preferences inform a Taylor-rule specification that ultimately relates news of inflation shocks to the real interest rate. The third objective is to model how the central bank policy framework—inflation targeting or otherwise—determines the market's

perceptions about the stance of monetary policy. To achieve the third objective, I use an optimal policy rule to explore how the central bank policy framework determines its credibility for low and stable inflation. The fourth objective is to use an event-study approach to estimate how commodity and foreign exchange prices respond to inflation announcements. Based on my model, if the central bank's commitment to low and stable inflation is credible, commodity and foreign exchange prices should respond negatively to inflation announcements.

This paper consists of five chapters including this introduction. This first chapter introduces the purpose of this study and show how the study is proposed. This chapter also provides the central hypothesis and objectives to conduct the study. The second chapter reviews the extant literature relevant to this study. The third chapter provides the research design and empirical models that I use to analyze my central hypothesis. This chapter also includes the definitions and descriptions of the data I use for this study. The fourth chapter provides the analysis of the data and reports the empirical results. This chapter also provides many of the tables and figures needed to describe the results. Finally, the fifth chapter provides the conclusions from the study.

CHAPTER 2: LITERATURE REVIEW

Many studies examine the effects of aggregate shocks on commodity prices. Aggregate shocks include monetary policy shocks in the forms of, say, money supply surprises in 1980s (Frankel & Hardouvelis, 1985) and federal funds rates target shocks in the 1990s (Gospodinov & Jamali, 2013). Aggregate shocks also include supply shocks, which force central banks to choose between low and stable inflation and sustained output growth, because such shocks move inflation and output in opposite directions. In contrast, demand shocks move inflation and output in the same direction and, thus, do not force central banks to choose between inflation and output objectives (Cecchetti et al., 2002).

Aggregate shocks can affect commodity prices by changing expected real interest rates or expected inflation. Whether the shock changes real interest rates or expected inflation depends on the market's perception of the stance of monetary policy. If a central bank is perceived as credibly committed to low and stable inflation, then the market will regard the inflationary effects of a supply shock as transitory, because the market reasons that the central bank will reverse these effects. In this case, expected real interest rates rise while inflation expectations remain unchanged (or anchored). However, if a central bank is not credibly committed to low and stable inflation, then the market will regard the inflation effects of a supply shock as permanent, because the market reasons that the central bank will not reverse these effects. In this case, expected real interest rates do not rise because nominal interest rate rise only one-for-one with expectations of inflation.

In a seminal article, Frankel (1985) proposed that commodity prices should be studied as an important indicator of inflationary expectations, because, in response to aggregate shocks, commodity prices adjust faster than the (relatively sluggish) prices of manufactured goods and services. As early as the 1970s, Okun (1975) argued all goods could be divided into two sectors: customer goods and auction goods. Following Okun, Frankel and Hardouvelis (1985) renamed these two sectors manufactured goods (and services) and basic commodities (or agricultural and mineral commodities), and assumed the key distinction between these two sectors was that the former are differentiated products traded in imperfectly competitive markets, so their prices are sticky in the short run; meanwhile, the latter are homogenous products traded in perfectly competitive markets, thus their prices are flexible and, thus, adjust instantaneously to aggregate shocks. According to this assumption, any effects of monetary policy announcements on commodity prices likely occur shortly after the announcement.

Frankel and Hardouvelis (1985) and Frankel (1986) emphasize the important role of expectations in the price formation process when money supply shocks occur; this research reflects the emphasis at that time that policymakers and researches placed on the monetary aggregates. In particular, suppose the Federal Reserve Board announced an unintended increase in the growth rate of the money supply. If the market perceived this increase as an indication that the Fed would maintain this higher growth rate, the market would revise its expectations of inflation upward. Consequently, commodity prices would rise, as investors shifted out of money and into commodities. In contrast, if the market perceived this increase as an indication that the Fed would contract the money supply and thus reverse the effects of the shock, the market would not revise its expectations of

inflation. However, the market would expect a rise in the real interest rate. Consequently, commodity prices would fall.

Thorbecke and Zhang (2009) find that in the 1970s and after 1989, federal funds rate target increases raised and lowered gold and silver prices, respectively. They attributed these inverse responses of gold and silver prices to the fund rate increases in the two different periods to different inflation expectations. In particular, they argue that responses of market participants to the increase of the federal funds rate depend on how these participants interpret the Fed's credibility. For the period of the 1970s, Thorbecke and Zhang (2009) agree with C. D. Romer and Romer (2000) that the Federal Reserve had private information about future inflation and thus the market would rely only on the Fed's forecasts. When the federal funds rate increased, market participants would infer that an expansionary monetary policy was likely to occur in the near future because they thought the Federal Reserve would not hit its target, and therefore they revised their inflation expectations upward. Thus, in the 1970s, federal funds rate increases led to higher inflation expectations, which in turn raised commodity prices. Whereas, for the period after 1989, the authors agree with Gurkaynak et al. (2003) that surprise increases in the federal funds rate target raised (short-term) real interest rates and lowered future inflation expectations because the Federal Reserve had earned more credibility than it had in the 1970s. This is to say, faced with an increase in the federal funds rate, market participants believed in the Fed's inflation-fighting credibility; thus, they revised their inflation expectations lower. High interest rates led to higher real interest rates and lower inflation expectations. Both of these responses worked to lower commodity prices.

To sum up, the effect of federal funds rate increases on expected inflation may have varied over time; and the effect has depended on the Fed's credibility in fighting inflation. When, in the 1970s, the Fed's anti-inflationary policies were not credible, long-term expected inflation increased, which in turn drove up commodity prices. When, in the 1990s, the Fed's policies were credible, long-term expected inflation fell (because real interest rates rose), which in turn drove down commodity prices.

According to Bernanke et al. (1999), central bank credibility in financial markets depends on delivering low and stable inflation. Inflation in the U.S. in the 1970s was high and volatile, while inflation since 1990 has been less volatile. Bernanke argues that the Fed's credibility was much weaker in the 1970s than since the 1990s; this argument is consistent with the conclusion of Thorbecke and Zhang (2009): in response to the federal funds rate increases, gold and silver prices rose during 1970s because of the Fed's poor credibility, which raised the expectations of inflation; whereas gold and silver prices fell after the1990s because of the Fed's higher credibility, which raised real interest rates.

Similarly, there are central-bank credibility studies based on the oil-price surges in the 1970s. Authors of these studies attribute high oil prices to high inflation expectations. For example, Barsky and Kilian (2002) argue that in the 1970s oil prices tended to rise because loose monetary policy resulted in higher expectations of inflation. The higher inflation expectations in the 1970s seem to be consistent with Bernanke's argument that inflation in the U.S. in the 1970s was high and volatile because the Federal Reserve lacked credibility in 1970s, so that inflation expectations would rise when supply shocks occurred (Bernanke et al., 1999). Similarly, Anzuini et al. (2010) examine the effect of monetary policy shocks on commodity prices, and also focus on the case of oil

to explore the channel through which monetary policy shocks influence commodity prices. The authors present empirical evidence suggesting that monetary policy shocks affect commodity prices mainly through market participants' higher expectations of inflation.

Cornell and French (1986) gauge the responses of real interest rates and expected inflation to surprises in the weekly money supply announcements between October 6, 1977 and March 23, 1984. They find that expected inflation, as opposed to expected real interest rates, rose when the money supply rose unexpectedly. Armesto and Gavin (2005) also estimate the commodity futures market's reaction to surprises in the Fed's interest rate target. They show that during 1988-2001, short-term expected inflation responded positively and significantly to surprises in the federal funds rate target, whereas real interest rates did not respond to federal funds rate surprises.

The above literature emphasizes how increases in the federal funds rate target raise commodity prices by increasing the market's inflation expectations. When the Fed does not credibility commit to low and stable inflation, changes in the federal funds rate translate into changes in inflation expectations. In comparison, when the Fed credibly commits to low and stable inflation, changes in the federal funds rate translate into changes in the real interest rate. Under this situation, for example, a decrease in the federal funds rate lowers the real interest rate and, thereby, leads to higher commodity prices.

Frankel (2006) demonstrates how changes in interest rates affect commodity prices through three channels: namely, inventories, speculation, and the incentive for

extracting commodities. More specifically, low interest rates reduce firms' opportunity costs of carrying inventories and thereby increase firms' demand for storable commodities. Additionally, low interest rates entice speculators to sell interest-earning financial assets and buy commodities because financial assets become less attractive when interest rates are low. Finally, low interest rates create a disincentive to extract exhaustible commodities today because of the decreased opportunity cost of delaying extraction.

Based on the above channels, Frankel (2006) provides empirical evidence of a negative relationship between real commodity prices and real interest rates. He relates surges in commodity prices to looser Federal Reserve monetary policy, and concludes that reductions in interest rates could increase commodity prices by decreasing the real interest rate. In his work he emphasizes an overshooting model and attributes the rise in commodity prices to market responses to monetary policy surprises. Similarly, Taylor (2009) presents a monetary explanation for the peaks in commodity prices. He argues that oil prices increased in 2007 and 2008 because the Federal Open Market Committee reduced interest rates, which caused the real interest rate to fall.

Gospodinov and Jamali (2013) test how federal funds rate shocks affect individual commodity prices for the metals and energy groups as well as commodity price indexes in the period of 1990 to 2009. Based on several empirical tests, the authors find that surprise decreases in the federal funds rate tend to increase individual and aggregate commodity prices. They also find that the decrease in the federal funds rate raises both nominal and real prices of commodities. These, together, seem to suggest that

in the period of 1990 to 2009, the decrease in the federal funds rate affected commodity prices through a decrease in the real interest rate. This is consistent with Frankel (2006).

Despite the vast literature on the effect of money supply announcements or federal funds rate target changes on commodity prices, there is little work on the effect of inflation (or price) shocks on commodity prices. The current norm in monetary policy is the inflation-targeting framework. So studying how commodity prices respond to inflation shocks under an inflation-targeting framework is sensible.

Bernanke et al. (1999) describe inflation-targeting frameworks and identify important reasons for adopting these frameworks. The authors state that in an inflation targeting framework, a central bank announces numerical targets for inflation and specifies that controlling inflation is a long-run goal of monetary policy. Another common feature is a specific policy for bringing inflation back to target in circumstances where the central bank has missed the target. Also, inflation-targeting central banks often adopt a relatively transparent policy approach that entails fairly detailed communication with the public.

Bernanke et al. (1999) also discuss the framework of the Bank of Canada's inflation targeting process and show how, when, and why the Bank of Canada adopted its targets. The authors explain that John Crow, the governor of the Bank of Canada in 1988, made it clear that the long-run monetary policy objective for the Bank of Canada should be price stability, which central bankers generally define as low and stable inflation. After substantial progress in reducing the inflation rate was already evident, the Bank of Canada announced, in February 1991, its inflation-targeting framework. Since then,

several countries have adopted inflation targeting, and no country has abandoned it. A noted exception to this group is the United States, where the framework for monetary policy is informed by a dual mandate to maintain both high employment and low and stable inflation. However, inflation targeting has many advocates in the United States. Those advocates argue that the economy could benefit from an inflation-targeting framework, which ensures low and stable inflation by enhancing central bank credibility. This enhanced credibility affords the central bank flexibility to stabilize the real economy. In any case, by the late 1990s, the United States seemed to settle on an implicit inflation-targeting framework for monetary policy (Goodfiriend, 2005).

Modern central banks set—explicitly or implicitly—inflation targets and follow interest-rate rules with the aim of achieving these targets. In order to achieve a medium term target of inflation or some combination of inflation and real economy activity targets, central banks adjust a near-term policy instrument, such as the short-term interest rate, in response to inflation shocks. This adjustment in general follows some specific monetary policy rules. For example, Taylor (1999) analyzed interest rate rules that describe how the Federal Reserve adjusts the federal funds rate in response to the state of the economy. When there is an inflation shock, such that the actual inflation rate exceeds the target inflation rate, according to Taylor, in order to keep its inflation target, the Federal Reserve tightens monetary policy; this tightening should raise the federal funds rate by more than one-for-one with the increase in the inflation rate. This is to say, Taylor (1993) argues monetary policy should move the interest rate in the same direction and by a greater amount than observed movements in inflation—this is called the Taylor principle. By following the Taylor principle, inflation reverts to its equilibrium (target-

value) quickly. That is, in response to inflation shocks central banks increase the nominal interest rate more than one for one with the rise in the inflation rate. Thus, the rise in the nominal interest rate corresponds to a rise in the real interest rate. The resulting co-movements between inflation and the real interest rate render inflation shocks transitory.

An inflation shock is a supply shock. Supply shocks force the central bank to choose to minimize either inflation or output variability. In other words, in response to a supply shock, minimizing inflation variability is costly in terms of output variability. Cecchetti et al. (2002) demonstrate how aggregate supply shocks force a central bank to implement monetary policy according to its preferences regarding inflation and output variability. In particular, by modeling dynamic relationships between output, inflation, and the short-term interest rate, the authors demonstrate how the central bank adjusts its policy instrument (short-term interest rate) to achieve an optimal combination of low and stable inflation and sustained economic growth.

In the inflation-targeting framework, in response to a supply shock, a central bank must choose to minimize inflation variability if it is credibly committed to its inflation target. When a central bank chooses to minimize inflation variability, it follows the Taylor principle to raise the real interest rate in response to a positive inflation shock.

In summary, a central bank's policy framework—inflation targeting or otherwise—is informed by the central bank's preference regarding inflation and output variability, which in turn determines whether the Taylor principle holds. As the literature I have reviewed here reveals, although the effects of monetary supply shocks on commodity prices have been widely studied, the effect of aggregate supply shocks,

particularly inflation shocks, remains largely unexplored. As I demonstrate in a model I propose in chapter 3, how inflation shocks affect commodity prices reveals the extent of central bank credibility and, thus, the effectiveness of a given monetary policy framework—inflation-targeting or otherwise.

CHAPTER 3: METHODOLOGY AND DATA

In this chapter, I present how this study is designed. At the beginning of this chapter, I introduce the theoretical background on which the estimation model is based. Then I specify how I structure empirical models that are used to test the working hypothesis of this study. Finally, I provide definitions and descriptions of the data I use in this study. In the appendix, I present detailed derivations associated with the model and additional tables associated with the data.

3.1 Background

Frankel and Hardouvelis (1985) test the credibility of the Federal Reserve regarding its commitment to money growth targets through the reactions of commodity prices to money supply announcements. Following Okun (1975), the authors emphasize that commodity prices, unlike most manufactured goods prices that are sticky in the short run, adjust quickly—"even from minute to minute" (Frankel & Hardouvelis, 1985)—in response to monetary policy shocks. Thus, because commodity prices are flexible, they should clearly indicate how inflation expectations respond to money supply shocks. If market participants expect higher money supply growth, and consequently higher inflation, they will shift out of money and into commodities, thus driving up commodity prices; in this case, central bank credibility (as an inflation fighter) is low. In contrast, if market participants expect lower money supply growth, and consequently lower inflation, they will shift into money and out of commodities, thus driving down commodity prices; in this case, central bank credibility is high (Frankel & Hardouvelis, 1985). In other words, commodity prices are positively related to inflation expectations, which reflect

central bank credibility. For this reason, Frankel and Hardouvelis (1985) propose to test central bank credibility through the reactions of commodity prices to news of monetary policy shocks in the form of unexpected changes in the money supply. Specifically, when an unexpected increase in the money supply is announced, and market participants believe the central bank is committed to its monetary target, they expect the central bank to counteract this increase—and, thus, tighten the money supply by raising the nominal interest rate—in the near future. Because the nominal interest rate equals the real interest rate plus expected inflation (money growth rate), market participants' expectations of tightening monetary conditions cause the real interest rate to rise as well. The higher real interest rate leads market participants to shift into interest-earning financial assets and out of commodities, driving down commodity prices. In contrast, if market participants do not believe the central bank is committed to its monetary target, they do not expect the central bank to counteract the unexpected increase in the money supply. Rather, they regard the unexpected increase in the money supply as an indicator of the central bank's new, looser monetary policy; thus, participants revise their inflation expectations upward. They shift out of interest-earning financial assets and into commodities, driving up commodity prices.

In summary, the public's expectations of inflation for the near future are related to the central bank's credibility, and these expectations are revealed in the behavior of commodity prices. Following news of a positive monetary policy shock, the real interest rate rises and inflation expectations do not change if central bank monetary policy is credibly committed to low and stable inflation; whereas, the real interest rate does not change and inflation expectations rise if policy is not credibly committed. Although the

nominal interest rate rises in both cases, commodity prices respond unambiguously: commodity prices fall if the central bank is credibly committed and rise otherwise.

Following the seminal work of Frankel and Hardouvelis (1985), I design this study to test central bank credibility at the Bank of Canada and the Federal Reserve under alternative monetary policy regimes; I do so by testing the reactions of commodity and foreign exchange prices to inflation shocks. Unlike the money supply shocks studied by Frankel and Hardouvelis (1985), inflation shocks are supply shocks. In the context of monetary policy, supply shocks differ from demand shocks in one key respect: demand shocks move inflation and output in the same direction, whereas supply shocks force policymakers to choose to minimize either inflation or output variability. In other words, in response to a supply shock, minimizing inflation variability is costly in terms of output variability.

In my study, I focus on the effect of inflation shocks, because modern central banks do not target the money supply; rather, most target some combination of inflation and real economic activity. Therefore, rather than following the specific approach that Frankel and Hardouvelis (1985) take, I develop my own model to estimate how inflation shocks affect commodity and foreign exchange prices. In particular, the model demonstrates conditions under which commodity and foreign exchange prices will fall in response to a rise in the real interest rate. As I explain below, this relationship between asset prices and inflation shocks can reveal whether expected inflation is well anchored under an inflation-targeting policy relative to some other monetary policy framework. First I explore how real commodity prices are related to real interest rates by using the same approach as Frankel (2006). Then, based on a macroeconomic model, I investigate

how news of inflation shocks affects real interest rates, which in turn affect commodity and foreign exchange prices.

3.2 Empirical Model

3.2.1 Real Interest Rates and Real Commodity Prices

To test whether market expectations of inflation are anchored, I explore a relationship between commodity prices and interest rates by following Frankel (2006), who takes the relationship from Dornbusch (1976), who models the relationship between foreign-exchange prices and interest rates. As in Dornbusch (1976), I first reproduce the essential features of this relationship for a small, open economy with perfect capital mobility. In this case, if the domestic currency is expected to depreciate, the domestic interest rate on asset, i, must equal to the foreign interest rate, i^*, plus the expected rate of depreciation of the domestic currency, x, which is specified in Equation 1.

$$i = i^* + x \qquad (1)$$

In addition, the expected rate of depreciation of the domestic currency, x, is proportional to the difference between the log of the current exchange rate, e, and the log of the long-run exchange rate, $\bar{e}$, which is specified in Equation 2, where $\theta > 0$.

$$x = -\theta(e - \bar{e}) \qquad (2)$$

Substituting Equation 2 into Equation 1 yields Equation 3.

$$e - \bar{e} = -\frac{1}{\theta}(i - i^*) \qquad (3)$$

According to Equation 3, the difference between current and long-run exchange rates is inversely proportional to the difference between domestic and foreign interest rates. That is, a higher domestic interest rate relative to the foreign interest rate will appreciate the domestic currency, so the domestic currency price of foreign exchange falls below its long-run equilibrium value until the expected depreciation of the domestic currency exactly offsets the increase in domestic interest rate. Thus, the current exchange rate, defined here as the domestic currency price of a foreign currency—that is, units of domestic currency per unit of foreign currency—is inversely proportional to the domestic interest rate.

Based on Dornbusch (1976), Frankel (2006) argues that commodity prices also overshoot in response to monetary policy shocks because commodities, like foreign exchange, are flexible-price goods in both the short and long run. Thus, Frankel (2006) substitutes commodity prices for exchange rates and the convenience yield for the foreign interest rate as specified in Equation 4; here, the domestic interest, i, equals a convenience yield, c, which I assume is constant, plus the expected change in the commodity price, s_t [1].

$$i_t = c + E_t \Delta s_t \tag{4}$$

Next, I assume regardless of how the real commodity price departs from its long-run value in response to a supply shock, the price will return to its long-run equilibrium value according to market participants' rational expectations. As specified in Equation 5,

---

[1] c is comprised of the convenience yield, which reflects the benefits of holding commodity inventories minus storage costs and a risk premium for carrying commodity inventories.

the expected change in the real commodity price, $E_t \Delta(s_t - p_t)$, is proportional to the difference between the log of the current real commodity price, q_t, and the log of the long-run real commodity price, $\bar{q}$, where $q = s - p$, and p is the aggregate price level.

$$E_t[\Delta(s_t - p_t)] \equiv E[\Delta q_t] = -\theta(q_t - \bar{q}) \tag{5}$$

Combining Equation 4 and 5, by eliminating $E_t \Delta s_t$ and writing Δp_t as π_{t+1}, yields Equation 6.

$$q_t - \bar{q} = -\frac{1}{\theta}(i_t - E_t \pi_{t+1} - c) \tag{6}$$

In Equation 6, the left side is the real commodity price, which is measured relative to its long run equilibrium value, and the right side is the real interest rate, which is measured relative to the convenience yield. According to Equation 6, the real commodity price, q_t, is inversely proportional to the real interest rate, $i_t - E_t \pi_{t+1}$.

Following Equation 6, and for the sake of demonstration, I test the relationship between real interest rates and real commodity prices over the period of 1972 to 2005 for Canada and the U.S. I use data of monthly long-term interest rates, the core Consumer Price Index (CPI), commodity price indexes and producer-price indexes for all commodities. I obtain the monthly long-term interest rate and core CPI from OECD Main Economic Indicators (OECD-MEI) for both Canada and the United States. I compute the monthly inflation rate from the monthly core CPI, which excludes volatile food and energy sectors. I obtain the monthly data on commodity price indexes for Canada from the Bank of Canada. Because the U.S. commodity price index is

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unavailable, I use the producer price index for all commodities instead. I obtain the producer price index-commodities from the U.S. Department of Labor, Bureau of Labor Statistics.

To test this relationship, I regress real commodity prices on real interest rates. To compute real commodity prices, I take the log of the monthly commodity price index minus the log of the monthly core CPI. To compute real interest rates, I use Equation 7.

$$r_j = i_j - [\ln(CPI_j) - \ln(CPI_{j-12})] * 100$$

(7)

Where, r_j is the real interest rate, i_j is the monthly long-term interest rate, j stands for the month, and $[\ln(CPI_j) - \ln(CPI_{j-12})]*100$ is the monthly inflation rate calculated as the same-month percentage change in the core CPI.

After I get real commodity prices and real interest rates, I use OLS to estimate the relationship between the two datasets. The results are shown in Figures 3 and 4 for Canada and the U.S., respectively. As shown in Figures 3 and 4, real commodity prices are negatively related to real interest rates in both Canada and the U.S. Although in practice, this relationship may not hold precisely because many factors other than real interest rates potentially influence commodity prices, these figures provide some evidence that the negative relationship implied by Equation 6 (i.e., the real commodity price, q_t, is inversely proportional to the real interest rates, $i_t - E_t\pi_{t+1}$) is empirically valid. I report regression results in Table 1.

Figure 3: Canadian Real Commodity Price Index vs. Real Interest Rate, monthly, 1972-2005
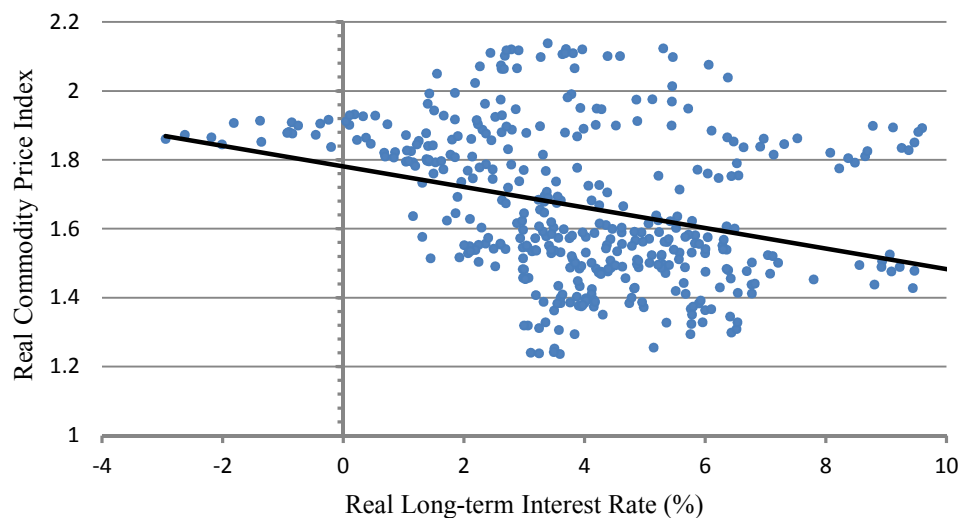
Sources: Bank of Canada; OECD-MEI.

Figure 4: US Real Commodity Price Index[2] vs. Real Interest Rate, monthly, 1972-2005
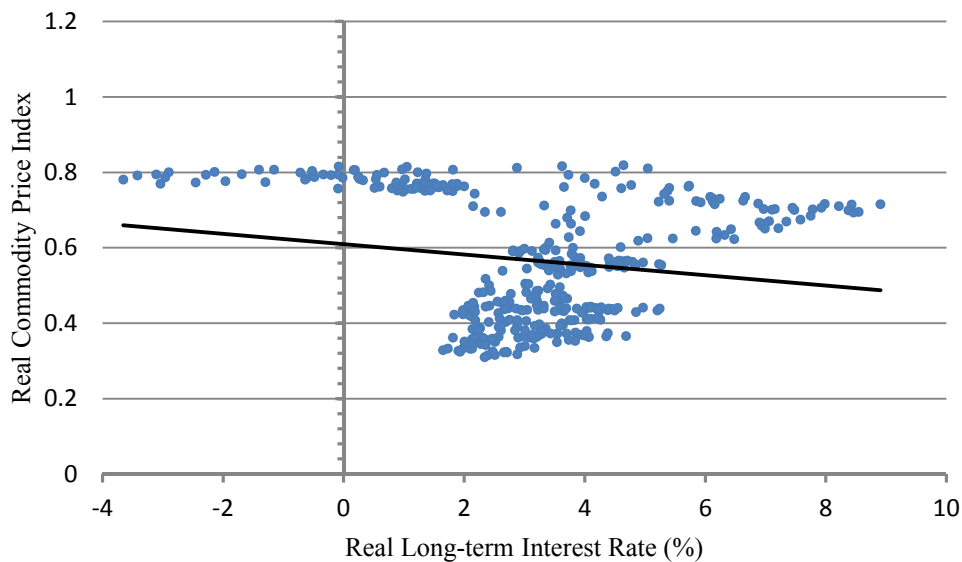
Sources: U.S. Department of Labor, Bureau of Labor Statistics; OECD-MEI.

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[2]The US commodity price index is represented by producer price index in all commodities.

Table 1: Regression of real commodity prices on real interest rates

Real Commodity Price Index and Real Interest Rate Sample: 1972-2005 (408 monthly observations) real commodity prices in log units and real interest rates in %					
Country	Constant	Coefficient	t-statistic	P-value	R-squared
Canada	1.781	-0.030***	-6.55	0.000	0.096
	(0.021)	(0.005)			
U.S.	0.609	-0.014***	-3.61	0.000	0.031
	(0.014)	(0.004)			

Notes: *** indicates significance of coefficient at the 1% level
(Standard errors are given in parentheses.)
Sources: Bank of Canada; U.S. Department of Labor, Bureau of Labor Statistics; OECD-MEI.

The coefficients in Table 1 represent the percentage change in real commodity prices due to a one-percentage point change in real interest rates. For Canada, a one percentage point increase in real interest rates is related to a 3 percent decline in real commodity prices. For the U.S., a one percentage point increase in real interest rates is related to a 1.4 percent decline in real commodity prices. For both countries, real commodity prices are negatively related to the real interest rates. The t-statistics indicate that the negative relationships are significant at the 1 percent level for both countries. In each case, the small R-squared together with the large t-statistic value indicate that the real interest rate is related to real commodity prices, but, not surprisingly, little of the variation in commodity prices is explained by variation in real interest rates. There are many other factors in addition to real interest rates that potentially explain real commodity prices, including weather, political vicissitudes, and so on.

Equation 6 shows that commodity prices could, in principle, reveal how market participants perceive the stance of central bank monetary policy. This is to say, if market

participants interpret a supply-shock induced inflation surprise as a new, looser monetary policy that the central bank has chosen not to reverse, participants will raise their expectations of inflation ($E_t\pi_{t+1}$), and thereby the nominal interest rate (i_t) will rise one for one with expected inflation; consequently, the real interest rate ($i_t - E_t\pi_{t+1}$) will not change and, accordingly, the real commodity price (q_t) will not respond to the announcement of the shock. In contrast, if market participants interpret the inflation surprise as a one-time event that the central bank will reverse, they will expect the central bank to raise the real interest rate ($i_t - E_t\pi_{t+1}$) by raising the nominal interest rate (i_t) without any change of their expectations of inflation ($E_t\pi_{t+1}$); consequently, the real commodity price (q_t) will fall below its long-run equilibrium until the expected rise in the commodity price offsets the higher expected real interest rate.

In summary, the nominal interest rate could increase [decrease] because expected inflation increases [decreases] or because the expected real interest rate increases [decreases]. Identifying which increase [decrease] is responsible for the nominal interest rate increase [decrease] identifies the market's perception of the central bank's credibility. In other words, identifying the cause of the nominal interest rate increase—expected inflation or the expected real interest rate—could reveal whether the central bank has credibly anchored the public's expectations of inflation. I hypothesize that the Bank of Canada anchored expected inflation because the adoption of an inflation-targeting framework affords the Bank of Canada credibility, whereas, the Federal Reserve did not anchor expected inflation to the extent that Canada did because the Fed

did not explicitly adopt an inflation-targeting framework (during my sample period).

Next, I introduce a macroeconomic model to test this hypothesis.

3.2.2 Monetary Policy and Real Interest Rates

Based on Galí (2008) and D. Romer (2012), I specify a macroeconomic model in which central-bank preferences inform a Taylor-rule specification that ultimately relates news of inflation shocks to the real interest rate. To begin, I assume a household of an infinitely lived representative agent who maximizes the objective function specified in Equation 8, subject to the budget constraint specified in Equation 9.

$$E_0 \sum_{t=0}^{\infty} \beta^t U(C_t, N_t) \tag{8}$$

$$P_t C_t + D_t B_t \leq B_{t-1} + W_t N_t \tag{9}$$

Where, C_t represents the quantity consumed of the single good, and N_t represents working hours of household members. The marginal utility of consumption $U_{c,t}$, is assumed to be positive and diminishing, while the marginal disutility of working, $-U_{n,t}$, is positive and increasing. For t=0, 1, 2......, P_t is the price of the consumption good, thus, $P_t C_t$ represents total consumption expenditures. Additionally, B_t represents the quantity of one-period, nominally riskless discount bonds purchased in period t and maturing in period $t+1$. Each bond pays one unit of money at maturity and its price is D_t, where $D_t \equiv \frac{1}{1+i}$. Lastly, W_t represents the nominal wage.

Utility takes the form specified in Equation 10.

$$U(C_t, N_t) = \frac{C_t^{1-\sigma}}{1-\sigma} + \frac{N_t^{1+\varphi}}{1+\varphi} \qquad (10)$$

In this case, a standard variational argument yields the Euler equation specified in

Equation 11.

$$D_t = \beta^t E_t \left(\frac{C_{t+1}^{-\sigma}}{C_t^{-\sigma}} \frac{P_t}{P_{t+1}} \right) \qquad (11)$$

Taking logs and linearizing the Euler equation yields Equation 12:

$$\ln C_t = \ln C_{t+1} - \frac{1}{\sigma} \ln[(1+r_t)\beta] \qquad (12)$$

To get this expression into a more tractable form, I introduce three simplifications. First, I

substitute Y_t for C_t using the fact that all production is consumed. Second, for small

values of r, $\ln(1+r) \approx r$; thus, I replace $\ln(1+r)$ with r. Finally, I suppress the constant

term, $-\frac{1}{\sigma} \ln \beta$.

These changes yield a simplified new Keynesian IS curve specified in Equation 13.

$$y_t = E_t(y_{t+1}) - \frac{1}{\sigma} r_t \qquad (13)$$

This new Keynesian IS curve shows that output is inversely related to the real interest

rate in the goods market. Specifically, an increase in the real interest rate reduces the

quantity of investment because the cost of borrowing for investment is higher. The reduction in planned investment lowers planned expenditure, which in turn lowers output.

In addition, I assume the central bank follows the (Taylor) interest-rate rule specified in Equation 14, where i_t is the nominal interest rate, which according to the Fisher effect is specified in Equation 15.

$$i_t = a\pi_t + by_t \tag{14}$$

$$i_t = r_t + E_t(\pi_{t+1}) \tag{15}$$

In Equation 14, π_t and y_t represent inflation and output, each relative to its long-run equilibrium values, the logs of which are normalized to zero in this model. This interest-rate rule stipulates how much the central bank should change the nominal interest rate in response to changes in inflation and output. In particular, the rule stipulates that for each one-percent increase in inflation, the central bank should raise the nominal interest rate by more than one percentage point (i.e. $a > 1$)—this is called the Taylor principle.

In Equation 15, r_t is the real interest rate, and $E_t(\pi_{t+1})$ is the expected inflation rate.

Finally, I model the supply side of the economy with the Phillips curve specified in Equation 16[3].

$$\pi_t = E_t(\pi_t) + \lambda y_t + \varepsilon_t^s \tag{16}$$

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[3] A popular alternative to this Phillips curve is the so-called new Keynesian Phillips curve, and a big difference in New Keynesian Phillips curve compared to the standard Phillips curve is that it depends on expected future inflation, instead of expected current inflation, i.e. $E_t(\pi_{t+1})$ instead of $E_t(\pi_t)$.

The Phillips curve shows that the inflation rate depends on three forces: namely, expected inflation rate, the deviation of output from its natural level, and supply shocks.

Because I use this model to demonstrate how supply shocks (ε_t^s), which force the central bank to choose to stabilize inflation or output, affect the real interest rate in the short run, I further simplify the IS curve (Equation 13): I suppress the expected-output term and set $\sigma = 1$; the result is Equation 17.

$$y_t = -r_t \tag{17}$$

Additionally, I assume inflation expectations are adaptive, i.e., $E_t(\pi_t) = \pi_{t-1}$. The adaptive expectations of inflation impose the condition that disinflation is costly in terms of output; otherwise, the central bank's choice to mitigate inflation is not a difficult one.

Combining Equation 14, 15, and 17 by eliminating i_t and y_t yields Equation 18, which relates the real interest rate to the inflation rate.

$$r_t = \frac{a-1}{1+b}\pi_t \tag{18}$$

Equation 18 implies that in the case where $a > 1$, the Taylor principle holds. That is, in response to an inflation shock, the real interest rate rises to cool the economy; in this case, the nominal interest rate increases more than one for one with the inflation rate. Moreover, in the case where $a > 1$, the solution for the inflation rate is specified in Equation 19.

$$\pi_t = \sum_{k=0}^{\infty} \left(\frac{1+b}{1+b+\lambda(a-1)} \right)^{k+1} \varepsilon_{t-k} \qquad (19)$$

Thus, the steady-state inflation rate is zero: the effects of supply shocks on inflation do not persist when $a > 1$.

Finally, because Equation 18 holds in every period, in Equation 20 I express the real interest rate in terms of unanticipated inflation (i.e., the inflation shock), $\pi_t - \pi_{t-1}$.

$$r_t = r_{t-1} + \frac{a-1}{1+b}(\pi_t - \pi_{t-1}) \qquad (20)$$

Equation 20 implies that when $a > 1$, the inflation shock leads the central bank to raise the real interest rate; and this rise of the real interest rate increases along with the magnitude of a. When $a = 1$, the inflation shock does not affect the real interest rate; rather, the unanticipated rise in inflation effectively reflects a new normal. In other words, it is crucial to know the magnitude (relative to 1) of a in order to characterize the credibility of the central bank. Specifically, if the central bank is credible, then a positive inflation shock raises the real interest rate, $a > 1$. The a is an interest-rate rule parameter specified in Equation 14 and is associated with the Taylor principle. In the next section, following Cecchetti et al. (2002), I use an optimal policy rule to explore how the central bank policy framework—inflation targeting or otherwise—determines the magnitudes of a.

3.2.3 The Optimal Policy Rule

Normally, a central bank conducts monetary policy by setting a near-term policy instrument, such as a nominal interest rate, in order to achieve over the medium term its optimal combination of low and stable inflation and sustained economic growth. In practice, the use of an interest rate as the main policy instrument has often taken place in conjunction with some inflation target. In other words, policymakers set—explicitly or implicitly—an inflation target and change interest rates with the aim of achieving such a target. In addition, as Cecchetti et al. (2002) demonstrate, a central bank endeavors to achieve this optimal outcome subject to the constraints imposed on it by the dynamic structure of the economy—in particular, the dynamic relationships between output, inflation, and the short-term interest rate.

In the context of the model I specify above, we can think of the nominal interest-rate rule (Equation 14) as the solution to an optimization problem in which the central bank minimizes Equation 21, the expected value of a loss function that is quadratic in (log) output deviations from trend (y_t) and inflation deviations from target (π_t), where, in this case, the output trend and the inflation target are both normalized to zero. Equation 22 and 23 specify the constraints imposed by the dynamic structure of the economy.

$$L = E[\alpha\pi^2 + (1-\alpha)y^2] \qquad (21)$$

$$\pi_t = -\lambda r_t + \varepsilon_t \qquad (22)$$

$$y_t = -(r_t + \frac{1}{\omega}\varepsilon_t) \qquad (23)$$

Here, $-\omega$ is the slope of the aggregate demand curve and λ is the slope of the

aggregate supply curve. According to Equation 22, the central bank offsets the

inflationary effect of a supply shock by raising the (real) policy instrument (r_t);

meanwhile, according to Equation 23, the central bank offsets the recessionary effect of a

supply shock by lowering the policy instrument. Thus, because a supply shock moves

inflation and output in opposite directions, the central bank must choose to minimize

either inflation or output variability. The central bank policy framework, reflected here by

the term α in Equation 21, informs this choice. For example, when $\alpha = 1$, the central bank

minimizes inflation variability, only, and disregards output variability.

In this problem, the optimal interest-rate rule (Equation 14) generally takes the

form in Equation 24, where the optimal policy instrument is a linear function of the

supply shock.

$$r_t = z\varepsilon_t \tag{24}$$

Substituting this optimal rule into Equations 22 and 23, taking the variances of output and

inflation, and plugging these variances into Equation 21 yields the loss function in terms

of z and the parameters of the model; minimizing this loss function with respect to z

yields z as a function of the slope of the aggregate demand curve ($-\omega$), the slope of the

aggregate supply curve (λ), and α.[4]

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[4] $Z = \dfrac{\alpha\lambda - (1-\alpha)\dfrac{1}{\omega}}{\alpha\lambda^2 + (1-\alpha)}$

Thus, the solution for α is expressed implicitly in Equation 25 in terms of the

variability of output (σ_y^2), the variability of inflation (σ_π^2), and the slope of the aggregate

supply curve (λ). In Appendix I, I derive α.

$$\frac{\sigma_\pi^2}{\sigma_y^2} = \left(\frac{1-\alpha}{\lambda\alpha}\right)^2 \tag{25}$$

Solving Equation 22 and 23 by eliminating r_t and substituting the resulting

expression for ε_t into Equation 24 yields a real-interest rate rule; thus, a and b in the

corresponding nominal interest-rate rule specified in Equation 14 take the forms specified

in Equation 26 and 27.

$$a = 1 + \frac{\alpha\lambda\omega - (1-\alpha)}{(1-\alpha) + \alpha\lambda^2} \frac{1}{\omega + \lambda} \tag{26}$$

$$b = \lambda(1-\alpha) \tag{27}$$

Finally, replacing ω with the expression for it implied by the nominal interest-rate rule

(Equation 14) and the IS curve (Equation 17), yields Equation 28.

$$a = 1 + \frac{\lambda}{\frac{1}{\alpha} + \lambda^2 - 1} \tag{28}$$

Equation 28 shows that as α approaches 0, a approaches 1 and the Taylor

principle does not hold. In contrast, as α approaches 1, a grows larger than 1 and the

Taylor principle holds. In this case, according to Equation 20, inflation shocks

effectively raise the real interest rate because the central bank increases the nominal

interest rate more than one for one with the rise in the inflation rate. The resulting rise in the real interest rate in turn renders the inflation shock transitory. The value of α depends on the central bank's choice; this is to say, in the face of inflation shocks, the central bank must choose to minimize inflation variability or output variability. In an inflation-targeting policy framework, the central bank's commitment to maintain low and stable inflation is credible—α approaches 1 in Equation 28.

3.2.4 Monetary Policy and Commodity Prices: A Test of Central Bank Credibility

Equations 6, 20, and 28 are the three key equations of my model. From these equations, it is clear that real commodity and foreign exchange prices are inversely proportional to inflation shocks if $a > 1$; in this case, agents reason the central bank is averse to inflation and, thus, the inflation shock is a one-off event the central bank reverses. In contrast, if agents reason the central bank is not averse to inflation, then α approaches 0 so that a approaches 1; the inflation shock reflects a new normal and real commodity and foreign exchange prices are unrelated to inflation shocks. Thus, testing the relationship between commodity and foreign exchange prices and inflation shocks is tantamount to testing the central bank's credibility regarding its commitment to low and stable inflation.

To test the relationship, I conduct regression analyses in which the percentage change in the individual commodity and foreign exchange prices are dependent variables and the percentage change in the inflation rate (immediately after the most-recent inflation statistic is made public) is the independent variable; thus, I estimate regressions of the form specified in Equation 29.

$$\Delta s_t = \beta_0 + \beta_1 \Delta \pi_t + \varepsilon_t \qquad (29)$$

Where, Δs_t denotes changes of individual commodity and foreign exchange prices

between the opening price on the day that the government announces the new inflation

rate and the closing price one day before the announcement; $\Delta \pi_t$ represents inflation

shocks; ε_t represents all other supply shocks except news of the inflation shock. Because

this study is designed to test the immediate response (within several hours) of commodity

and foreign currency prices to announcements of inflation shocks, the news regarding

other supply disruptions is relatively unlikely to overwhelm asset-price responses to the

inflation announcement.

The sign of the coefficient, β_1, reflects central bank's credibility. Estimates of β_1

should be negative if a central bank is credible, and nonnegative if the central bank is not

credible. This is because that when an inflation shock occurs, an inflation-targeting

central bank chooses to minimize inflation variability and, thus, raises the real interest

rate. When the real interest rate rises, commodity prices and foreign-exchange prices fall

as investors shift out of commodities and into money. Therefore, I expect a negative

relationship between commodity and foreign-exchange prices and inflation shocks (

$\beta_1 < 0$) if the central bank is credible. Specifically, I expect the β_1 is negative for the

post-IT period for Canada because the explicit adoption of inflation targeting afforded the

Bank of Canada credibility. For the U.S., because the Federal Reserve implicitly adopted

inflation targeting in the post-IT period, I expect some estimates of β_1 to be negative, as

well; though, I expect evidence of credibility to be stronger for Bank of Canada. In

contrast, if the central bank is not credible, investors interpret the inflation shock as a new normal; they shift out of money and into commodity markets. Therefore, I expect a nonnegative relationship between commodity and foreign-exchange prices and inflation shocks ($\beta_1 \geq 0$) in the period of pre-IT for both Canada and the U.S..

3.3 Definitions and Descriptions of the Data

In order to test responses of commodity and foreign exchange prices to inflation shocks, I use the data of individual commodity futures prices, the Canada/U.S. foreign exchange rate, the Trade Weighted U.S. Dollar Index (Major Currencies[5]), and the core CPI. Again, because it is less volatile, I use the core CPI to measure the inflation rate and the inflation shock. I define the inflation shock as the difference between the announced actual inflation rate and the expected inflation rate. I assume that the public formulates its expectation of the inflation rate in the next month based on the actual inflation rate in the current month. Based on this adaptive-expectation formulation, I treat the actual inflation rate in the current month as the expected inflation rate in the following month.

The Canadian commodity price data consist of futures prices for canola oil and feed wheat traded on the Winnipeg Grain Exchange (WGE) between 1982 and 2005. The U.S. commodity price data consist of futures prices for corn, oats, soybeans, soybean meal, soybean oil, and wheat traded on the Chicago Board of Trade (CBOT/CMEGROUP) and spring wheat traded on the Minneapolis Grain Exchange (MGEX). I obtain the data of individual commodity futures prices (on a daily frequency)

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[5] A weighted average of the foreign exchange value of the U.S. dollar against a subset of the broad index currencies that circulate widely outside the country of issue. Major currencies index includes the Euro Area, Canada, Japan, United Kingdom, Switzerland, Australia, and Sweden.

from the Commodity Research Bureau (CRB). For each commodity, the futures prices are from futures contracts of varying maturities; these contracts may overlap at a moment in time. To compile the time series of commodity future prices, I use only the prices from the nearby future contract. In particular, beginning from the first day of the study period, I use the prices from the nearest maturing contract until the last day of that contract (i.e., the day when the maturity month is reached). Then, I use the prices from the next nearest maturing contract. Repeating this until the last day of the study period, I construct the time series of each commodity's futures price.

For each commodity, the difference of commodity futures prices between the opening price on the day when the inflation rate is announced (once every month) and the closing price on the day before the new inflation rate is announced is the measure of the change of the commodity futures price for that month; this measure gauges how the market responds to the announcement of the inflation shock. In general, the opening price is the individual commodity futures price at 10:30am Eastern Time on the trading day on the Winnipeg Commodity Exchange for Canada and the Chicago Board of Trade and the Minneapolis Grain Exchange for the US; the closing price is the individual commodity futures price at 2:15pm Eastern Time the day before. I obtain the inflation-rate release (announcement) dates from Statistics Canada and the US Department of Labor, Bureau of Labor Statistics. The monthly release dates of inflation rate are almost always different for each country. Both Canada and the U.S. release CPI data at 8:30am Eastern Time, which is two hours before the starting time of commodity futures trading. Within this time (2 hours), I reason the market has enough time to respond to the announcement of inflation—a response reflected in the opening prices of commodities—and little else.

I obtain the data on foreign exchange rates from the Federal Reserve Economic Database (FRED) at the daily frequency. The Canada / U.S. and the U.S. / Canada foreign exchange rates are used for Canada and the U.S., respectively. The Canada / U.S. and the U.S. / Canada foreign exchange rate are noon buying rates in New York City for cable transfers payable in foreign currencies. The noon rates are calculated to reflect the trades that take place between 11:59 a.m. and 12:01 p.m. and are updated by about 12:45 p.m. ET at month-end and 12:30 p.m. ET on other business days, which is several hours after the inflation release time (8:30am ET); again, I measure its daily changes in these foreign exchange series in response to inflation shocks. Because the bulk of Canadian foreign trade (exports and imports) is always with the United States, the focus of attention for Canada is naturally the Canada / U.S. foreign exchange rate. I also use the Trade Weighted U.S. Dollar Index (Major Currencies) to measure the changes of the exchange rate for the U.S. The Trade Weighted U.S. Dollar Index is updated at about 16:30 p.m. ET, I also measure its daily changes in response to inflation shocks.

CHAPTER 4: RESULTS AND ANALYSIS

In this chapter, I report estimation results based on the models I specified in chapter 3. In addition, I present robustness checks to examine whether my model is effective in terms of testing the relationship between the announcement of inflation shocks and commodity and foreign-exchange prices.

4.1 The impact of announcements of inflation shocks on commodity and foreign-exchange prices

I estimate the impact of inflation shocks on commodity and foreign-exchange prices to explore whether the inflation shocks affect commodity and foreign-exchange prices through the channel of real interest rates. In other words, if positive inflation shocks result in negative commodity and foreign-exchange price changes through the channel of higher real interest rates, then expected inflation is anchored; thus, the inflation-targeting framework is credible.

In the case of Canada and the US, because the Bank of Canada explicitly adopted an inflation-targeting framework while the Federal Reserve System did not, I hypothesize that, after adopting its inflation-targeting framework, the Bank of Canada earned credibility that the Federal Reserve System continued to lack. To test this hypothesis, I estimate the effect of inflation shocks on commodity and foreign-exchange prices in Canada and the United States over the period of 1982 to 2005. Additionally, to gain insight into how monetary policy is perceived over time, I divide the sample period into two distinct sub-periods representing different monetary policy regimes. The first period is 1982 to 1991 and the second period is 1996 to 2005. I end the first sub period in 1991,

when the Bank of Canada explicitly announced that it had adopted an inflation-targeting framework for its monetary policy. However, the Canadian inflation-targeting framework did not mature until early 1993 (Bernanke et al., 1999). So the two subsamples represent pre-IT and post-IT policy regimes, respectively. As such, the two subsamples offer a useful, natural experiment with which to compare monetary policies in the two countries over time.

In order to investigate the response of commodity and foreign-exchange prices to an inflation shock, I estimate regression equations of the form specified in Equation 28. I structure the data so that the announcement of inflation takes place prior to the market's open, so the dependent variable Δs_t is calculated as 100 times the difference between the natural log of the opening price directly after the announcement of inflation and the natural log of the closing price just prior to the announcement. In each month, the inflation data are released at 8:30am Eastern Time, which is two hours earlier than the market's open (10:30am). So I assume the announcement effects of inflation shocks on commodity futures prices and foreign exchange prices occur on the day when the actual inflation rate is released. I also assume that, aside from the inflation announcement, no other relevant information is released between the market close and the following day's open, or if other information is released it is of a random nature and, thus, captured by the error term in my regression specification. Nevertheless, given the relatively small role that inflation shocks play in shaping commodity price movements, I expect relatively low R-squared estimates.

I calculate the inflation shock using Equation 33:

$$\Delta\pi_t = \{[\ln(CPI_{t,j}) - \ln(CPI_{t-1,j})]*100 - [\ln(CPI_{t,j-1}) - \ln(CPI_{t-1,j-1})]*100\}*100 \quad (33)$$

where t represents the year, and j represents the month. In this equation, I use the actual inflation rate of month (j-1) as the expected inflation rate for month j; thus, I assume inflation expectations are adaptive.

Because the inflation rate is released on a specific day every month, I take the commodity and foreign-exchange prices on that specific day and the prior day of each month over the period 1982 to 2005, and then calculate first differences. For each asset type and for Canada, there are 120 observations for the pre-IT period and 119 observations for the post-IT period. I omitted one observation on 2/22/2005 because the closing price was not available. In Table 2, I present summary statistics for the dependent variable—Canadian Commodities and exchange rate. The average refers to the average of the percentage change of commodity and foreign exchange prices, and a negative minimum value is a log value of a number less than one which means the opening price on the inflation release day is lower than the closing price on the prior day. Here the approximate equation $\ln(1 + a) \approx a$ is applied, and a represents the percentage change. The same is applied to values reported in Table 4.

Table 2: Summary Statistics for Canadian Commodities and exchange rate

Commodity	Period	average	standard deviation	maximum	minimum
Wheat	1982-1991	0.014	0.717	3.312	-1.792
	1996-2005	-0.05	0.753	2.658	-2.301
Canola oil	1982-1991	-0.065	1.1	4.492	-9.042
	1996-2005	0.048	0.73	2.413	-2.744
Canadian/US Dollar Exchange Rate	1982-1991	-0.028	0.233	0.655	-0.988
	1996-2005	0.081	0.447	1.385	-1.124

Note: 119 observations for 1982-1991; 120 observations for 1996-2005

In Table 3, I report how commodity and foreign currency prices respond to inflation shocks over the two periods for Canada.

Table 3: Estimated Effects of Inflation Shocks on Commodity and Foreign Exchange Prices, Canada

Commodity	Period	Coefficient	t-statistic	P-value	R-squared
Wheat	1982-1991	-0.001 (0.002)	-0.74	0.459	0.005
	1996-2005	-0.005 (0.003)	-1.85^{**}	0.068	0.028
Canola oil	1982-1991	0.001 (0.003)	0.19	0.849	0.000
	1996-2005	-0.004 (0.003)	-1.61^{***}	0.109	0.022
Canadian/US Dollar Exchange Rate	1982-1991	0.000 (0.001)	0.58	0.564	0.003
	1996-2005	-0.004 (0.002)	-2.18^{*}	0.031	0.039

Notes: * indicates significance of coefficient at the 5% level
    **indicates significance of coefficient at the 10% level
    (Standard errors are given in parentheses)
I also compute standard errors and the t-and P-values using the robust regression method (i.e., regression with robust standard errors), and the results are almost identical. This also applies to other regression results reported in this thesis.

The results in Table 3 indicate that, in the post-IT period, commodity prices respond negatively and significantly to inflation shocks at the 10% and 11% level for wheat and canola oil, respectively. In addition, the Canadian/US dollar exchange rate is also significantly affected by inflation shocks at the 5% level in the post-IT period. In comparison, there is no significant response in the pre-IT period, regardless of the sign of the coefficients. This result, together with the observed (and theoretically substantiated)

negative relationship between real commodity prices and real interest rates, provides strong evidence that inflation shocks affected commodity and foreign-exchange prices during the post-IT period primarily through the channel of the real interest rates instead of the channel of expected inflation rates. In particular, in the post-IT period, market participants perceived an inflation shock as a one-time event the central bank would reverse, so they raised their expectations of the real interest rates and, consequently, commodity and foreign-exchange prices fell below their long-run equilibriums until the expected rise of each offset the higher expected real interest rate. The different response of commodity and foreign-exchange prices to inflation shocks in the pre- and post-IT periods indicates that expected inflation is well anchored in post-IT period, and I reason this is because of the inflation-targeting framework. This in turn indicates that the inflation-targeting framework is effective and the Bank of Canada gained credibility by adopting it.

In order to compare the U.S. monetary policy effects with Canada, I test the responses of commodity and foreign-exchange prices over the same time periods for the U.S.: the pre-IT period from 1982 to 1991 and the post-IT period from 1996 to 2005. The U.S. monetary experience offers a rich comparison in this case, because although the U.S. settled on an implicit inflation-targeting framework by the late 1990s (Goodfiriend, 2005), it did not explicitly announce its adoption of an inflation-targeting framework. Therefore, if an explicit inflation-targeting framework is uniquely effective, the Bank of Canada should be more credible than the Federal Reserve in terms of safeguarding its inflation target.

In Table 4, I present summary statistics for the dependent variable—the U.S.

Commodities and exchange rates.

Table 4: Summary Statistics for US commodities and exchange rates
(120 observations for each period)

Commodity	Period	average	standard deviation	maximum	minimum
Corn	1982-1991	-0.032	2.619	5.754	-21.380
	1996-2005	0.201	1.277	6.236	-3.624
Oats	1982-1991	0.139	2.139	6.175	-14.123
	1996-2005	-0.167	3.098	6.236	-28.414
Soybeans	1982-1991	0.127	1.426	4.395	-8.173
	1996-2005	-0.061	0.914	3.250	-5.645
Soybean Meal	1982-1991	0.162	1.461	5.436	-6.723
	1996-2005	-0.167	0.857	3.170	-3.950
Soybean Oil	1982-1991	0.200	1.232	4.809	-5.293
	1996-2005	0.101	0.759	4.619	-2.382
Wheat(on CBOT)	1982-1991	-0.062	3.254	6.436	-32.757
	1996-2005	0.118	1.078	5.573	-1.739
Wheat(on MGEX)	1982-1991	-0.061	1.605	2.772	-14.944
	1996-2005	-0.067	1.225	5.080	-7.271
US/Canada exchange rate	1982-1991	0.012	0.241	0.804	-0.863
	1996-2005	0.005	0.415	1.258	-1.433
Trade Weighted exchange rate	1982-1991	-0.079	0.449	1.141	-1.463
	1996-2005	0.000	0.414	1.233	-1.021

In Tables 5 and 6, I report responses of U.S. commodity and foreign-exchange

prices over the periods of pre-IT and post-IT, respectively. Corresponding to the U.S.

inflation release dates, I calculate 120 observations for each commodity (14 commodities

in total) and foreign-exchange prices in the pre- and post-IT periods. As shown in Table

5, in the pre-IT period, the sign of the coefficients between the commodity and foreign-

exchange prices and inflation shocks are mixed and there are no significant relationships.

Table 5: Estimated Effects of Inflation Shocks on Commodity and Foreign Exchange Prices over the period 1982-1991, the U.S.

Commodity	Coefficient		t-statistic	P-value	R-squared
Corn/No.2 Yellow	-0.003	(0.010)	-0.32	0.753	0.001
Corn(Pit Only[6])	-0.003	(0.010)	-0.32	0.753	0.001
Oats/White Heavy	0.005	(0.008)	0.58	0.563	0.003
Oats(Pit Only)	0.005	(0.008)	0.58	0.563	0.003
Soybeans/No.1 Yellow	-0.001	(0.005)	-0.20	0.842	0.000
Soybeans(Pit Only)	-0.001	(0.005)	-0.20	0.842	0.000
Soybean Meal/48% Protein	0.001	(0.005)	0.10	0.919	0.000
Soybean Meal(Pit Only)	0.001	(0.005)	0.10	0.919	0.000
Soybean Oil/Crude	0.001	(0.004)	0.18	0.854	0.000
Soybean Oil(Pit Only)	-0.002	(0.004)	-0.36	0.722	0.001
Wheat/No.2 Soft Red	-0.006	(0.012)	-0.53	0.594	0.002
Wheat(Pit Only)	-0.006	(0.012)	-0.53	0.594	0.002
Wheat/Spring 14% Protein	-0.006	(0.006)	-0.97	0.333	0.008
Wheat, Spring(Pit Only)	-0.006	(0.006)	-0.97	0.333	0.008
US/Canada exchange rate	0.000	(0.001)	-0.33	0.745	0.001
Trade Weighted exchange rate	0.001	(0.002)	0.33	0.746	0.001

Note: Each commodity has 120 observations
   (Standard errors are given in parentheses)

In Table 6, I report regression results for the post-IT period. Similar to the pre-IT period, the responses of commodity and foreign-exchange prices to inflation shocks are mixed (with both negative and positive coefficients). However, there are indeed a few (three out of sixteen) commodities and exchange rates for which the coefficients are negative and significant. For example, in the case of Soybean Meal (Pit Only), the coefficient is significant at the 1% level, and a one-percentage increase in the inflation rate causes a 1.8% decline in Soybean meal prices. In addition, the response of US/Canada exchange price is also significant and negative at the 5% level, i.e., a one-percentage increase in the inflation

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[6]Pit only refers to the trading that occurs at a specific venue where buyers and sellers communicate using open outcry method to communicate with each other, different from what occurs in an electronic trading platform.

rate causes a 0.7% decline in US/Canada exchange price. Those significantly negative

coefficients appear to be consistent with the effect of the inflation-targeting framework. This

could be explained by the change in monetary regimes from a dual mandate to maintain both

high employment and low and stable inflation to an implicit inflation-targeting framework

from the pre-period to the post-IT period.

Table 6: Estimated Effects of Inflation Shocks on Commodity and Foreign Exchange Prices over the period 1996-2005, the U.S.

Commodity	Coefficient		t-statistic	P-value	R-squared
Corn/No.2 Yellow	0.016	(0.009)	1.76**	0.081	0.026
Corn(Pit Only)	0.005	(0.010)	0.47	0.639	0.002
Oats/White Heavy	-0.006	(0.025)	-0.23	0.817	0.001
Oats(Pit Only)	-0.017	(0.025)	-0.68	0.500	0.004
Soybeans/No.1 Yellow	0.007	(0.005)	1.34	0.183	0.015
Soybeans(Pit Only)	-0.008	(0.007)	-1.07	0.288	0.010
Soybean Meal/48% Protein	-0.009	(0.005)	-1.65**	0.101	0.023
Soybean Meal(Pit Only)	-0.018	(0.007)	-2.78*	0.006	0.061
Soybean Oil/Crude	0.004	(0.005)	0.72	0.471	0.004
Soybean Oil(Pit Only)	0.001	(0.006)	0.17	0.862	0.000
Wheat/No.2 Soft Red	0.012	(0.008)	1.54	0.126	0.020
Wheat(Pit Only)	0.009	(0.009)	1.10	0.272	0.010
Wheat/Spring 14% Protein	0.014	(0.009)	1.56	0.122	0.020
Wheat, Spring(Pit Only)	0.012	(0.010)	1.24	0.217	0.013
US/Canada exchange rate	-0.007	(0.003)	-2.05*	0.043	0.034
Trade Weighted exchange rate	-0.001	(0.003)	-0.24	0.808	0.001

Notes: * indicates significance of coefficient at the 5% level
      ** indicates significance of coefficient at the 10% level
      Each commodity has 120 observations
      (Standard errors are given in parentheses)

The pre-IT period of the US falls into the period when Paul Volcker was the

chairman of the Fed, and when the Fed had a credibility problem, which showed up as

"inflation scares"—sharply rising long-term bond rates reflecting long-term inflation

expectations. Although the Volcker Fed had made some preemptive actions against inflation, another "inflation scare" occurred in 1987 when stock market crashed near the end of Volcker's term as the chairman of the Fed. In summer of 1987, Greenspan became the Chairman of the Fed in place of Volcker. To overcome the 1987 stock market crash, the Greenspan Fed took a series of policy actions to reverse the loss of Fed's credibility for low and stable inflation. In practice, the Greenspan Fed's preemptive actions again inflation can be viewed as the emergence of an implicit inflation-targeting policy regime. Particularly, owing to the 1994 preemptive interest rate policy actions, inflation and inflation expectations were anchored more firmly than ever before, and by 1996 the bond rate was down to around 6 percent which was viewed as "the death of inflation" (Goodfiriend, 2005). The change of the Fed's credibility for low and stable inflation and inflation expectations from the Volcker to Greenspan era may at least in part explain the statistically significant and negative results that I obtained in the post-IT period.

Overall, there is no apparent difference between the response of the commodity and foreign-exchange prices to inflation shocks in the pre- and post-IT periods for the US, and thus there is less compelling evidence of a change (toward credibility) in the markets' perception about U.S. monetary policy. However, for the US, the switch of responses in Soybean Meal and US/Canada exchange prices from insignificant in the pre-IT period to significantly negative in the post-IT period is consistent with the fact that the Greenspan Fed gained credibility for low and stable inflation and, thus, low and stable inflation expectations, thanks to the implicit inflation-targeting framework adopted by the Greenspan Fed.

4.2 Robustness tests of the model

To check the robustness of my methodology, I apply it to the U.S. experience during the periods of November 3, 1978-October 4, 1979 and July 7, 1980-November 5, 1982, which Frankel and Hardouvelis (1985) have examined. Between these two periods, there was a monetary regime shift: the Fed (under the leadership of Paul Volcker) announced a change in operating procedures on October 6, 1979 and imposed credit controls from March to July 1980 in order to get the money growth rate under control. The U.S. experienced a sharp increase in the level and volatility of inflation and inflation expectation during 1970s, which resulted in a near total collapse of the Fed's credibility for low inflation. In 1979 when Volcker became the chairman of the Fed, the Volcker Fed endeavored to get the inflation down and restore the Fed's credibility for low inflation. At that time, the Volcker Fed realized that it is difficult to disinflate if the fed continued to make monetary policy by pursuing interest rate policy (target the federal funds rate). Because if the Fed chose to increase the real interest rate to stabilize the economy by raising the nominal interest rate, its efforts would need to be understood and trusted by the public. However, having experienced the collapse of credibility, the public could underestimate the Fed's determination to bring down inflation. Hence, it was difficult for the Fed to judge how a given nominal interest rate policy action would translate into an adjustment of the real interest rate. Therefore, on October 6, 1979, under Chairman Paul Volcker, the FOMC changed its monetary policy approach to target money growth rates, which would allow interest rates to rise substantially and, thus, lean against inflation pressures (Goodfiriend, 2005). Figure 5 shows inflation and nominal interest rates around the period of the Volcker Fed, in which the Fed experienced a

change in monetary operating procedure. From the picture, after July 1980 inflation starts to decrease and, the trend of nominal interest rates is opposite to the trend of inflation. The opposite trends reflect anchored inflation after 1980, which may be explained by the change of monetary operating procedure.

Figure 5: Inflation and Nominal Interest Rates in the U.S., 1975-1985
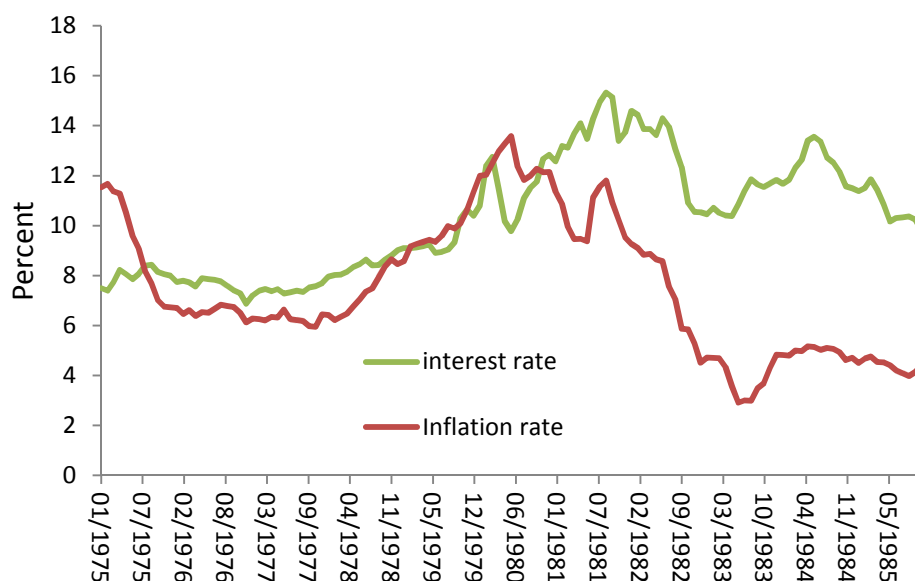
Source: OECD main economic indicators

Given these new operating procedures and the Great Inflation that preceded them, I hypothesize that in the pre-October 1979 period, commodities and foreign-exchange prices were not responding negatively to positive inflation shocks. In contrast, I hypothesize that in the post-July 1980 period, these prices did respond negatively to inflation shocks, because the market believed in the Fed's (credible) commitment to achieve its preannounced money growth targets and, thus, disinflate. Indeed, the result of Frankel and Hardouvelis (1985) show that some (though not nearly all) responses of commodities and foreign-exchange prices to money surprises—their measure of

announcements of inflation—changed from no significant relationship to negatively

significant from the pre-October 1979 to the post-July 1980 period.

Using my approach, I find a similar switch of responses to inflation shocks (as I

measure them) of commodities and foreign-exchange prices, as shown in Tables 7 and 8.

In particular, in the pre-October 1979 period, the responses reveal no clear sign pattern,

whereas in the post-July 1980 period, the responses are negative except for two wheat

series exchanged in MGEX (Wheat/Spring 14% Protein and Wheat, Spring (Pit Only))

and the Trade weighted exchange rate that positively reacts to inflation shocks. It is

interesting to note that the response of US/Canada exchange prices switch from an

insignificant positive coefficient of 0.004 to a significant negative coefficient of -0.001.

This result is similar to Frankel's result of for the Canadian dollar, for which the response

switches from an insignificantly negative coefficient of -0.011 to a significantly negative

coefficient of -0.077. Although Frankel's results in post-July 1980 period are all negative,

only a few cases (gold, cattle, the Swiss franc and Canadian dollar) are statistically

significant at 5% level. The general consistency between my test results and that of

Frankel and Hardouvelis (1985) for the same period suggests that my method used to test

the credibility of central bank is meaningful.

Table 7: Estimated Effects of Inflation Shocks on Commodity and Foreign Exchange
Prices over the period 11/3/1978-10/4/1979, the U.S.

Commodity	Coefficient		t-statistic	P-value	R-squared
Corn/No.2 Yellow	0.001	(0.005)	0.14	0.893	0.002
Corn(Pit Only)	0.001	(0.005)	0.14	0.893	0.002
Oats/White Heavy	-0.013	(0.008)	-1.54	0.158	0.209
Oats(Pit Only)	-0.013	(0.008)	-1.54	0.158	0.209
Soybeans/No.1 Yellow	0.001	(0.003)	0.24	0.815	0.006
Soybeans(Pit Only)	0.001	(0.003)	0.24	0.815	0.006

Soybean Meal/48% Protein	0.000	(0.003)	0.03	0.975	0.000
Soybean Meal(Pit Only)	0.000	(0.003)	0.03	0.975	0.000
Soybean Oil/Crude	0.000	(0.007)	0.02	0.981	0.000
Soybean Oil(Pit Only)	0.000	(0.007)	0.02	0.981	0.000
Wheat/No.2 Soft Red	-0.010	(0.005)	-2.06	0.070	0.320
Wheat(Pit Only)	-0.010	(0.005)	-2.06	0.070	0.320
Wheat/Spring 14% Protein	-0.004	(0.003)	-1.54	0.158	0.208
Wheat, Spring(Pit Only)	-0.004	(0.003)	-1.54	0.158	0.208
US/Canada exchange rate	0.004	(0.003)	1.28	0.233	0.154
Trade Weighted exchange rate	-0.002	(0.003)	-0.76	0.469	0.060

Note: Each commodity has 11 observations
(Standard errors are given in parentheses)

Table 8: Estimated Effects of Inflation Shocks on Commodity and Foreign Exchange Prices over the period 7/7/1980-11/5/1982, the U.S.

Commodity	Coefficient		t-statistic	P-value	R-squared
Corn/No.2 Yellow	-0.004	(0.005)	-0.76	0.456	0.022
Corn(Pit Only)	-0.004	(0.005)	-0.76	0.456	0.022
Oats/White Heavy	-0.001	(0.008)	-0.14	0.892	0.001
Oats(Pit Only)	-0.001	(0.008)	-0.14	0.892	0.001
Soybeans/No.1 Yellow	-0.001	(0.003)	-0.39	0.703	0.006
Soybeans(Pit Only)	-0.001	(0.003)	-0.39	0.703	0.006
Soybean Meal/48% Protein	-0.003	(0.002)	-1.11	0.279	0.045
Soybean Meal(Pit Only)	-0.003	(0.002)	-1.11	0.279	0.045
Soybean Oil/Crude	-0.002	(0.003)	-0.90	0.375	0.030
Soybean Oil(Pit Only)	-0.002	(0.003)	-0.90	0.375	0.030
Wheat/No.2 Soft Red	-0.001	(0.004)	-0.22	0.826	0.002
Wheat(Pit Only)	-0.001	(0.004)	-0.22	0.826	0.002
Wheat/Spring 14% Protein	0.001	(0.002)	0.47	0.645	0.008
Wheat, Spring(Pit Only)	0.001	(0.002)	0.44	0.661	0.008
US/Canada exchange rate	-0.001	(0.001)	-1.78[**]	0.086	0.109
Trade Weighted exchange rate	0.003	(0.001)	2.34[*]	0.027	0.174

Note: * indicates significance of coefficient at the 5% level
** indicates significance of coefficient at the 10% level
Each commodity has 28 observations
(Standard errors are given in parentheses)

In summary, I examine the responses of commodity and foreign-exchange prices to inflation shocks in the period of 1982 to 2005 for Canada and the U.S. For Canada, the responses of commodity and foreign-exchange prices to inflation shocks changed from effectively zero to negative from the period of 1982 to 1991 to 1996 to 2005, consistent with the expected result of the adoption of an inflation-targeting framework by the Bank of Canada in 1991. By adopting the framework, the Bank of Canada could better and more credibly maintain low and stable inflation. In comparison, the response of commodity and foreign-exchange prices to inflation shocks shows no clear sign pattern and, has only changed in a few cases from the period of 1982 to 1991 to 1996 to 2005 for the U.S. This change is not as strong as Canada. This is not a surprise, because the U.S. did not explicitly adopt the inflation-targeting framework. However, the changes in the cases of Soybean Meal and US/Canada exchange prices I study suggest that the Fed has earned some credibility for low inflation due to its adoption of an implicit inflation-target framework during 1996 to 2005. The comparison between the two sub-periods for Canada, as well as that between Canada and the U.S., provides strong evidence that the inflation-targeting framework is effective and, the central bank that explicitly adopts it should be more credible than the one does not.

CHAPTER 5: CONCLUSION

In the early 1990s, the Bank of Canada explicitly adopted an inflation-targeting framework for monetary policy, while the Federal Reserve did not. Instead, the Federal Reserve seemed to settle on an implicit inflation-targeting framework, at least until the late 1990s. In this study, I test whether the Bank of Canada achieved credibility for low and stable inflation because it adopted an explicit inflation-targeting framework and, likewise, whether the Federal Reserve achieved credibility for low and stable inflation because it adopted an implicit inflation-targeting framework.

To measure central bank credibility, I estimate how commodity and foreign-exchange prices respond in Canada and the United States to announcements of inflation shocks over the period of 1982 to 2005. Additionally, to gain insight into how monetary policy is perceived over time, I divide the sample period into two distinct sub-periods representing different monetary policy regimes: 1982 to 1991 represents the pre-IT policy regime and 1996 to 2005 represents the post-IT policy regime—explicit or otherwise.

The responses of commodity and foreign-exchange prices to inflation shocks reflect whether the market's inflation expectations are anchored, which in turn reflects central bank credibility for low and stable inflation. Specifically, commodity and foreign-exchange prices fall in response to a positive inflation shock if the market interprets the shock as a one-off event the central bank will reverse. This is because the market reasons that the central bank is credibly committed to its inflation target; thus, the market expects the central bank to raise real interest rates to get the inflation rate back on target. In this case, expected inflation is unchanged. The higher expected real interest rates make the

cost of storing commodities and foreign currencies higher and, thus, investors shift out of commodities and foreign currencies and into money; this shift drives down commodity and foreign-exchange prices. In contrast, commodity and foreign-exchange prices rise in response to a positive inflation shock if the market interprets the shock as a new, looser monetary policy stance. Because the central bank does not demonstrate credibility, the market adjusts its expectations of inflation upward in face of inflation shocks; the expected real interest rate is unchanged. The higher expectations of inflation induce investors to shift into commodities and foreign currencies and out of interest earning financial assets and, thus drive up commodity and foreign-exchange prices. In summary, commodity and foreign-exchange prices negatively respond to inflation shocks if the central bank is credible, because in this case the expected real interest rate rises while expected inflation is anchored. Whereas, commodity and foreign-exchange prices positively respond to inflation shocks if the central bank is not credible, because in this case the expected real interest rate is unchanged and expected inflation is revised upward.

My results indicate that, for Canada, there is no significant response of commodity and foreign-exchange prices to the announcements of inflation shocks in the pre-IT period, regardless of the sign of the coefficients. In comparison, all the commodity and foreign-exchange prices respond negatively and significantly to the announcements of inflation shocks in the post-IT period. That is, in the post-IT period, market participants perceived an inflation shock as a one-time event the central bank would reverse, so they raised their expectations of real interest rates without changing their expectations of inflation and, consequently, commodity and foreign-exchange prices fell according to the observed negative relationship between real commodity prices and real

interest rates. The different responses of commodity and foreign-exchange prices to inflation shocks in the pre- and post-IT periods indicate that expected inflation is well anchored in the post-IT period but not in the pre-IT period. The anchored expected inflation reflects that the Bank of Canada achieved credibility since its adoption of inflation-targeting. So I conclude that Canada's inflation-targeting framework amounts to a credible commitment to low and stable inflation.

For the US, in the pre-IT period, the sign of the coefficients between the commodity and foreign-exchange prices and the inflation shocks are mixed (with both negative and positive coefficients) and there are no statistically significant relationships. Similar to the pre-IT period, in the post-IT period, the responses of commodity and foreign-exchange prices to the announcements of inflation shocks are still mixed and, have only changed in a few cases from the sub-period of pre-IT to post-IT and the change is not as strong as Canada. This is not a surprise because the U.S. did not explicitly adopt an inflation-targeting framework. However, in the post-IT period, there are indeed a few (three out of sixteen) commodities and foreign-exchange prices for which the coefficients are negative and significant. Those significantly negative coefficients appear to be consistent with the effect of the Fed's implicit inflation-targeting framework. The switch of responses from insignificant to significantly negative could be explained by the change of the Fed's monetary regime from a dual mandate to maintain both high employment and low and stable inflation to an implicit inflation-targeting framework from the pre-period to the post-IT period.

Overall, the results of this study support my working hypothesis that by adopting an inflation-targeting framework for monetary policy, the Bank of Canada achieved a

relatively high degree of credibility in terms of maintaining low and stable inflation both relative to its past and relative to the Federal Reserve, which did not explicitly adopt an inflation-targeting framework (during my sample period). The comparison between the two sub-periods for Canada, as well as that between Canada and the U.S. provides strong evidence that the inflation-targeting framework is effective and, the central bank that explicitly adopts as a monetary policy framework should be more credible than the one does not.

In addition, I test the robustness of my model by applying the same method to the U.S. during the periods of November 3, 1978 to October 4, 1979 and July 7,1980 to November 5, 1982 that Frankel and Hardouvelis (1985) examined. Between these two periods, there was a monetary regime shift: the FOMC (under the leadership of Paul Volcker) changed its monetary policy approach from targeting the federal funds rate to targeting the money growth rate, which was then thought to be a better approach to controlling inflation. Frankel and Hardouvelis (1985) find that the responses of commodities and foreign-exchange prices to money surprises—their measure of announcements of inflation—changed from no significant relationship to negatively significant from the pre-October 1979 to the post-July 1980 period. Using my approach, I find a similar switch of responses to inflation shocks (as I measure them) of commodities and foreign-exchange prices. The general consistency between my test result and that of Frankel and Hardouvelis (1985) for the same period suggests that my method used to test the central bank credibility is effective.

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Appendix I: Derivation of α

Equation 25 is derived as follows.

$$L = E[\alpha\pi^2 + (1-\alpha)y^2] \tag{21}$$

$$\pi_t = -\lambda r_t + \varepsilon_t \tag{22}$$

$$y_t = -(r_t + \frac{1}{\omega}\varepsilon_t) \tag{23}$$

$$r_t = z\varepsilon_t \tag{24}$$

Substituting Equation 24 into Equations 22 and 23 and taking the variances of inflation

and output yields Equation 30 and 31.

$$\sigma_\pi^2 = (1-\lambda z)^2 \sigma_\varepsilon^2 \tag{30}$$

$$\sigma_y^2 = (z + \frac{1}{\omega})^2 \sigma_\varepsilon^2 \tag{31}$$

Substituting these expressions into Equation 21 yields Equation 32.

$$L = \alpha[(1-\lambda z)^2 \sigma_\varepsilon^2] + (1-\alpha)[(z + \frac{1}{\omega})^2 \sigma_\varepsilon^2] \tag{32}$$

Minimizing Equation 32 with respect to z yields $z = \dfrac{\alpha\lambda - (1-\alpha)\dfrac{1}{\omega}}{\alpha\lambda^2 + (1-\alpha)}$.

Finally, substituting the expression for z into Equations 30 and 31 yields Equation 25.

Appendix II: Data Specification

Country	Variables	Frequency	Source	Sample Size
Canada	Long-term interest rates	monthly	OECD - MEI	1/1971-12/2007
	Core CPI inflation[1]	monthly	OECD - MEI	1/1971-12/2007
	Commodity price index	monthly	Bank of Canada	1/1972-12/2007
	CPI release dates	monthly	Statistics Canada	1/1982-12/2005
	Commodity futures price	daily	CRB InfoTech CD - Futures	1/1982-12/2005
	Canada / U.S. Foreign Exchange Rate[2]	daily	Board of Governors of the Federal Reserve System	1/1982-12/2005
US	Long-term interest rates	monthly	OECD - MEI	1/1971-12/2007
	Core CPI inflation	monthly	OECD - MEI	1/1971-12/2007
	Producer price index	monthly	U.S. Department of Labor, Bureau of Labor Statistics	1/1972-12/2007
	CPI release dates	monthly	U.S. Department of Labor, Bureau of Labor Statistics	1/1982-12/2005
	Commodity futures price	daily	CRB InfoTech CD - Futures	1/1982-12/2005
	Trade Weighted U.S. Dollar Index: Major Currencies[3]	daily	Board of Governors of the Federal Reserve System	1/1982-12/2005

[1] Consumer prices - Annual inflation, all items non-food non-energy

[2] Canadian Dollars to One U.S. Dollar, Noon buying rates in New York City for cable transfers payable in foreign currencies.

[3] A weighted average of the foreign exchange value of the U.S. dollar against a subset of the broad index currencies that circulate widely outside the country of issue. Major currencies index includes the Euro Area, Canada, Japan, United Kingdom, Switzerland, Australia, and Sweden.

Appendix III: Commodity Futures Characteristics

Symbol	Commodity	Exchange[1]	Trading Hours (E.S.T.)[2]
WC	Canola / No. 1	WCE	10:30a.m. - 2:15p.m.
WW	Wheat, Domestic Feed/No. 3	WCE	10:30a.m. - 2:15p.m.
C-	Corn / No. 2 Yellow	CBOT/CMEGROUP	10:30a.m. - 2:15p.m.
2C	Corn (Pit Only)	CBOT/CMEGROUP	10:30a.m. - 2:15p.m.
O-	Oats / White Heavy	CBOT/CMEGROUP	10:30a.m. - 2:15p.m.
2O	Oats (Pit Only)	CBOT/CMEGROUP	10:30a.m. - 2:15p.m.
S-	Soybeans / No. 1 Yellow	CBOT/CMEGROUP	10:30a.m. - 2:15p.m.
2S	Soybeans (Pit Only)	CBOT/CMEGROUP	10:30a.m. - 2:15p.m.
SM	Soybean Meal / 48% Protein	CBOT/CMEGROUP	10:30a.m. - 2:15p.m.
2L	Soybean Meal (Pit Only)	CBOT/CMEGROUP	10:30a.m. - 2:15p.m.
BO	Soybean Oil / Crude	CBOT/CMEGROUP	10:30a.m. - 2:15p.m.
2B	Soybean Oil (Pit Only)	CBOT/CMEGROUP	10:30a.m. - 2:15p.m.
W-	Wheat / No. 2 Soft Red	CBOT/CMEGROUP	10:30a.m. - 2:15p.m.
2W	Wheat (Pit Only)	CBOT/CMEGROUP	10:30a.m. - 2:15p.m.
MW	Wheat / Spring 14% Protein	MGEX	10:30a.m. - 2:15p.m.
2M	Wheat, Spring (Pit Only)	MGEX	10:30a.m. - 2:15p.m.

[1] WCE, Winnipeg Commodity Exchange; CBOT/CMEGROUP, Chicago Board of Trade; MGEX, Minneapolis Grain Exchange.

[2] Trading hours quoted are as before 2006.