2018

THE IMPACT OF BIOFUEL POLICIES ON OVERSHOOTING OF AGRICULTURAL PRICES

Mahdi Asgari
University of Kentucky, mahdiasgari.1098@gmail.com
Author ORCID Identifier:
https://orcid.org/0000-0001-9098-1479

Digital Object Identifier: https://doi.org/10.13023/etd.2018.293

Recommended Citation

Asgari, Mahdi, "THE IMPACT OF BIOFUEL POLICIES ON OVERSHOOTING OF AGRICULTURAL PRICES" (2018). *Theses and Dissertations--Agricultural Economics*. 67.
https://uknowledge.uky.edu/agecon_etds/67

STUDENT AGREEMENT:

I represent that my thesis or dissertation and abstract are my original work. Proper attribution has been given to all outside sources. I understand that I am solely responsible for obtaining any needed copyright permissions. I have obtained needed written permission statement(s) from the owner(s) of each third-party copyrighted matter to be included in my work, allowing electronic distribution (if such use is not permitted by the fair use doctrine) which will be submitted to UKnowledge as Additional File.

I hereby grant to The University of Kentucky and its agents the irrevocable, non-exclusive, and royalty-free license to archive and make accessible my work in whole or in part in all forms of media, now or hereafter known. I agree that the document mentioned above may be made available immediately for worldwide access unless an embargo applies.

I retain all other ownership rights to the copyright of my work. I also retain the right to use in future works (such as articles or books) all or part of my work. I understand that I am free to register the copyright to my work.

REVIEW, APPROVAL AND ACCEPTANCE

The document mentioned above has been reviewed and accepted by the student’s advisor, on behalf of the advisory committee, and by the Director of Graduate Studies (DGS), on behalf of the program; we verify that this is the final, approved version of the student’s thesis including all changes required by the advisory committee. The undersigned agree to abide by the statements above.

Mahdi Asgari, Student

Dr. Sayed Saghaian, Major Professor

Dr. Carl Dillon, Director of Graduate Studies

THE IMPACT OF BIOFUEL POLICIES ON OVERSHOOTING OF AGRICULTURAL PRICES

DISSERTATION

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the College of Agriculture, Food and Environment at the University of Kentucky

By

Mahdi Asgari

Lexington, Kentucky

Co-Directors: Dr. Sayed Saghaian, Professor of Agricultural Economics
and Dr. Michael R. Reed, Professor of Agricultural Economics

Lexington, Kentucky

ABSTRACT OF DISSERTATION

THE IMPACT OF BIOFUEL POLICIES ON OVERSHOOTING OF AGRICULTURAL PRICES

The Federal Reserve has increased nominal interest rates since early 2016. It is expected that commodity prices will drop in response to this monetary intervention. The overshooting hypothesis explains that commodity prices are more flexible than manufacturing prices and therefore are more volatile. In this situation, it is expected that agricultural commodities decline significantly (i.e., overshoot) and gradually return to their long-run equilibrium. This adjustment behavior has implications for income stability and financial viability of farmers.

This research contributes to the overshooting literature by including the energy sector in the overshooting model. The interlinks between energy and other sectors in the economy as well as the vast resource allocation to biofuel production in recent decades demand more attention to the impact of energy on the dynamic adjustment path of relative prices' reaction to monetary shocks. We assume energy prices have independent adjustment path and include the links between the energy and agricultural sectors through biofuel production in our model. Our theoretical model shows that by including energy prices in the model, agricultural prices and the exchange rate overshoot less than the prediction of prior studies. This happens because we expect that flexible energy prices share the burden of the shock with other flexible prices in the model. We also describe how an increasing share of biofuels in the total fuel consumption will reduce the flexibility of energy prices.

In our empirical analysis, we use monthly data from January 1975 to December 2017 for three producer price indexes (i.e., agricultural commodities, energy, and industrial goods), exchange rates, and money supply to test the overshooting hypothesis. We found the series to be nonstationary and cointegrated of the order one, I(1). Thus, we estimated a vector error correction model to identify the short run adjustment parameters while maintaining the long-run relationships between the variables. We identify and control for three possible structural breaks in the data that coincide with two economic crises and the biofuel production era. We also estimated the empirical model using a sub-sample from January 1975 to March 1999 and compared the results with the findings in previous studies.

Our empirical results confirm the theoretical expectation that agricultural commodities adjust faster than manufacturing prices. The analysis of the impulse response functions shows that after a money supply shock, agricultural prices were the most responsive, followed by energy prices and exchange rates. In both full sample and the sub-sample, the volatility of prices and exchange rates happen during the first 5 to 10 months. The sluggish adjustment of manufacturing prices was evident from the corresponding impulse response functions.

The empirical evidence rejects the long-run money neutrality, consistent with the findings of previous empirical studies. Compared to previous models, our empirical model shows that including energy prices will reduce the extent to which agricultural commodities overshoot. Therefore we expect the disturbances to the farm income variability, in response to monetary policy, to be less than what prior model would have estimated. In this regard, energy prices are a stabilizing factor in this model. We find that increased share of biofuel from total fuel consumption would positively affect the overshooting of agricultural prices. So, higher biofuel mandates could reduce the flexibility of the energy prices and therefore have an adverse effect on the farm price stability.

KEYWORDS: Agricultural Prices, Monetary Shocks, Overshooting, Biofuel Policy, Dynamic Price Analysis

Mahdi Asgari
June 5, 2018

THE IMPACT OF BIOFUEL POLICIES ON OVERSHOOTING OF AGRICULTURAL PRICES

By

Mahdi Asgari

Dr. Sayed Saghaian
Co-Director of Dissertation

Dr. Michael R. Reed
Co-Director of Dissertation

Dr. Carl Dillon
Director of Graduate Studies

June 5, 2018

To my mother who devoted every moment of her life to my success and to my wife who believed in me and hold my hand through ups and downs.
To my father for all the things he taught me and to my brother for showing me how to overcome difficult times.

ACKNOWLEDGEMENTS

In completing the following dissertation, I am indebted to the insights and direction of several people. First, my Dissertation Co-Chairs, Dr. Sayed Saghaian and Dr. Michael Reed who were a true mentor to me throughout my Ph.D. program. Thank you both for your patience, dedication, and guidance that made this dissertation possible. Thank you for your support and invaluable advice beyond this research project that helped me to improve professionally and personally. Next, I wish to thank my Dissertation Committee, and Outside Examiner, respectively: Dr. John Schieffer, Dr. Adib Bagh, Dr. Tyler Mark, and Dr. Ana Herrera for their comments and suggestions that substantially improved the finished product.

In addition, I would like to thank Dr. Leigh Maynard as the Chair and Dr. Michael Reed and Dr. Carl Dillon as Directors of Graduate Studies for being supportive, morally and financially, of my academic endeavors while studying at the University of Kentucky. Also, I should thank Dr. Yuqing Zheng, Dr. Steven Buck, Dr. Tim Woods, Dr. Ani Katchova, and Dr. William Hoyt who provided research and teaching opportunities for me in various capacities. I appreciate the dedicated staff in our department, especially Rita Parsons, Janene Toelle, Karen Pulliam, and David Reese for their administrative and technical support. I am thankful to the AEC family for creating such a welcoming and constructive department.

Finally, I wish to thank my family and friends who also had an important role in this part of my life. My wife, Dr. Na Zuo, has been always a great supporter, outstanding colleague, and a true friend. I could never finish this work without her patience and faith in me. I am grateful to Scott W. Hall for all the conversations we had in our office. Many thanks to Jerrod Penn, Hua Zhong, Xiaojin (Eric) Wang, Mohammad Soltani and Mehdi Nemati for their friendship and support throughout these years.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1. Overshooting Hypothesis: An Overview

Introduction

The equilibrium real interest rate in the U.S. has been well below its historical levels, close to zero, for almost a decade. Currently, the only plausible path seems to be a gradual increase in the real rate through a set of contractionary monetary policies (Fischer 2016). There is no doubt that monetary policy affects commodity prices through real interest rates movements. However, the extent of such impact is debatable. The mechanism through which monetary policy impacts relative prices is explained by the overshooting model. This model is originally developed by Dornbusch (1976) to describe the foreign exchange market and later modified by Frankel (1986) in the context of commodity prices. Later, Saghaian, Reed, Marchant (2002) enhanced the model by combining the assumptions of the two previous studies. They defined a small open economy that includes assets market, agricultural commodity market, and industrial goods and services market. They, nor the succeeding literature, consider the energy sector in their models. In this study, we include the energy market in the model independently and account for the direct links between the energy sector and the agricultural sector through the production of the biofuels from agricultural commodities, like corn and soybeans.

To better understand the implications of the overshooting model, it is important to note that investors react to a monetary shock based on their interpretation of the change in the interest rate. If they suspect an increase in the inflation premium due to an increase in the nominal interest rate, then the excess demand for commodities and foreign exchange drive up prices. Conversely, an expectation of an increase in the real interest rates drives the prices down which is consistent with the overshooting explanation (Frankel 1984).

The interrelations between macroeconomics and the agricultural sector have been investigated in different frameworks. Some researchers focused on establishing causal relationships between money and agriculture.[1] Two distinct approaches have been developed on the adjustment path of commodity prices to monetary changes, to explain agricultural price movements. The "traditional structural approach" emphasizes the role of supply and demand factors[2] as the major price determinants. The alternative "monetarist approach" considers an active role for the money supply (Barnett, Bessler, and Thompson 1983). According to this explanation, agricultural prices, in the short run, deviate from their equilibrium in response to the expansionary monetary policy and then eventually arrive at their new steady state. (Tai et al. 2014; Anzuini, Lombardi, and Pagano 2013; Saghaian, Reed, Marchant 2002). The extent of such deviation varies based on the forecasting method, aggregation level and the sample used in different studies. In this view, although the stabilizing role of the steady money supply is not negligible, the internal dynamics of the sector remain the major factor in agricultural price performance (Saghaian, Reed, and Hasan 2006).

In this study, we model an open economy with flexible exchange rates, agricultural prices, and energy prices that represent asset market, commodity market, and energy market, respectively. We also include manufacturing prices that, by assumption, respond sluggishly to the monetary policy. Our theoretical model shows that the energy sector would share the burden of shocks with the other two flexible prices and therefore, the extent of overshooting for the commodity prices would be less than the prediction of previous

---

[1] For instance Perez and Siegler (2006) and Bessler and Lee (2002) apply graph-theoretic method using historical data from late 19th and early 20th century to investigate causal links between money and prices prior to the Great Depression.

[2] See Borensztein and Reinhart (1994) and, more recently, Knittel and Pindyck (2016).

models. We also show how introducing the biofuel production to the system could impact the flexibility of the energy prices and therefore the response of commodity prices to policy shocks. However, it seems that the rigidity caused by increasing share of biofuel in total fuel consumption is small at the current mandate levels.

To empirically test our theoretical model, we follow the time series econometric literature. We use monthly data for the agricultural producer price index, energy producer price index, industrial commodities producer price index, and the exchange rate from January 1975 to December 2017 to specify a vector autoregressive model which identifies the short run adjustment path of the price series and exchange rates in response to a positive money supply shock. Our results confirm previous empirical findings that agricultural prices respond faster than manufacturing prices to monetary innovations. However, including the energy prices in the model would partly absorb the shock and the extent of overshooting of agricultural prices in our model is less than prior estimations.

The fundamental characteristic that differentiates the behavior of various prices, included in the general price index, is their adjustment speed or in other words their flexibility. Significant developments in commodity markets during past decades resulted in higher flexibility in agricultural prices. On the other hand, to cope with market instability and mitigate the production risks, agricultural policies in the U.S. have evolved from land control to price control, to risk management, and revenue insurance programs in recent years. This gradual reform has also increased price flexibility (Townsend 2015; Zulauf and Orden 2016). Higher price flexibility in agriculture, compared to manufacturers, implies a faster response to macroeconomic shocks.[3] The extent to which each sector responds to a monetary innovation depends on the adjustment speed of its prices. Since agricultural commodities respond more quickly to changes in the money supply, they bear the burden of adjustment to the monetary shock in the short run (Frankel 1986a and 1986b; Stamoulis and Rausser 1987).

Therefore, stable increases in money supply are preferred by farmers if they are looking for price stability. Steady expansion in monetary policy would allow structural factors, supply, and demand, to determine the price in the markets whereas any abrupt money changes could destabilize agricultural markets in the short run (Saghaian, Reed, and Hasan 2006). The monetarist perspective can explain the link between the macroeconomic policy and price spikes in agricultural commodities in recent decades. Empirical studies noted that commodity price booms in both 1970s and 2000s succeeded expansionary monetary policies and considerable world liquidity due to U.S. trade deficits (Gilbert 2010). In this regard, identifying the mechanism and extent of the impact that monetary policy could have on the agricultural sector is essential.

Schuh (1974) pioneered in explaining how monetary policy in the United States affects agricultural commodities in international markets through its impact on interest rates, exchange rates, and relative prices. Dornbusch (1976) proposed a theoretical framework, i.e., the overshooting hypothesis, to explain the short run response of commodity prices to monetary policies. Since then, the overshooting hypothesis is used, theoretically and empirically, to explain the existence and analyze the extent of short-run

---

[3] This is well documented in early works of Cairnes (1873); Bordo (1980); Barnett, Bessler, and Thompson (1983); Devadoss and Meyers (1987); Orden and Fackler (1989); and Bessler and Lee (2002) who explained the responsiveness of commodity (relative) prices to monetary changes.

real effects of macroeconomic policies on the agriculture sector. When a temporary change in a price value extends beyond its long-run equilibrium, overshooting occurs (Saghaian, Reed, and Marchant 2002). Whether a price overshoots or undershoots, basically is determined by its adjustment speed to shocks. Prices with high adjustment speed are assumed flexible while other sluggish prices are called sticky. The extent of the overshooting depends on the relative weight of sticky to flexible prices in the price index (Stamoulis and Rausser 1987; Saghaian, Reed, and Marchant 2002).

The overshooting hypothesis formulation has been revised theoretically and tested empirically since Dornbusch. Saghaian, Reed, and Marchant (2002) extended the original model and defined an open economy with prices for agricultural commodities and manufactures having different adjustment paths. They considered agriculture and exchange rates as the flex-price sectors and manufacturing as the fixed-price sector. Overshooting of the flexible prices, exchange rates, and the agricultural sector can explain, to some extent, for the volatility in prices (Saghaian, Reed, and Marchant 2002).

In this literature, however, the energy sector has been ignored to avoid the complexity of the model mostly because the new linkages between energy and agriculture were not as important then. The role of energy as an intermediate good and one of the main factors of production is significant in the economy. The energy sector is seen as relatively flexible and could also respond to shocks independently. Any change in energy prices directly impacts total output and also the aggregate price index. On the other hand, reserves of traditional energy are depleting, and concerns over the climate change are raising which in turn intensify competition over natural resources to produce renewable energy. Biofuel production, specifically, has impacted the price of commodities like corn, soybean, and wheat. Major commodities experienced sharp price changes during the past decade.

While there is ample empirical evidence on the correlation of price changes across commodities, the historical record of relative prices reveal higher volatility in agricultural prices comparing to industrial prices (Knittel and Pindyck 2016). Significant price volatilities in the context of high food prices exacerbate its negative impacts. Many theoretical and empirical studies have been devoted to understand and explain the causation of high food prices. The linkage between high energy and commodity prices, exacerbated by biofuel policies, is the subject of many empirical studies (e.g., de Gorter, Drabik, and Just 2013; Chen and Khanna 2012; Elobeid *et al*. 2007). Energy prices directly impact agricultural production through the price of nitrogen used in fertilizers and through the price of fuel as a key determinant of cost in prior/post-harvest services. Thus the volatility in the energy market transmits to the agricultural sector, although the pass-through effect might be small (Gilbert 2010).

The price of crude oil experienced large swings in the 2008 and 2011, which coincided with high food prices.[4] On the other hand, the environmental concerns regarding the use of fossil fuels and higher oil prices resulted in a set of regulations and policies which consequently created and amplified the demand for biomass energy (de Gorter, Drabik, and Just 2015; Gilbert 2010). Diverting agricultural resources to biofuel production has been controversial during the past decade. Global food price crises of 2007-2008 and 2010-2011, once again, drew the attention of researchers to study the linkages between energy and agriculture sectors and the impact of energy policies on agricultural prices. The

---

[4] The price of crude oil in the United States stayed below $40 per barrel up to mid-2004, peaked at $145 in mid-2008, plummeted to $30 by the end of 2008 and reached to $110 in 2011.

so-called “Food versus Fuel” debate remains heated despite the fact that there is less disagreement among scholars on the profound direct and indirect impact of biofuel policies on agricultural producers and food consumers around the world. To make better sense of commodity price fluctuation, it is essential to understand these impacts (de Gorter, Drabik, and Just 2015).[5]

Considering interlinks between energy and other sectors is essential to identify the extent of price response to macroeconomic shocks. The contribution of this study is to include the energy sector in the theoretical model and analyze the extent of overshooting for the prices of four different sectors. In our model, it is expected that the extent of overshooting in agricultural prices decreases and energy prices share some burden of the adjustment to shocks. Introducing the energy sector adds complexity to the theoretical model yet provides a more realistic understanding of the agricultural sector’s response to economic shocks. Given the close links between agriculture and bioenergy production, the focus of this study is on identifying the time adjustment path of agricultural prices in response to macroeconomic shocks in the presence of energy policies. Therefore, the main objective of this study is to assess the determinants of the dynamic adjustment path for prices after a macroeconomic shock in an open economy that consists of agriculture, manufacturing, and energy sectors.

According to Stamoulis and Rausser (1987) and Saghaian, Reed, and Marchant (2002), the degree of overshooting is negatively correlated with the number of flexible prices in the price index. So, the main hypotheses to examine in this study is whether the

---

[5] de Gorter, Drabik, and Just (2015) emphasize that biofuel policies have significantly and substantially caused food prices to skyrocket in 2007 and 2011. Zilberman *et al.* (2012) discuss various methods that have been implemented to assess the impact of biofuels on commodity food prices and conclude that the role of biofuel policies on food prices are significant but less important.

close link between energy and agriculture enhance overshooting of agricultural prices. To establish the link between macroeconomics and agricultural commodity prices and test the overshooting hypothesis, three main conceptual assumptions should be considered.

These fundamental concepts are best explained by Frankel (1984). The first underlying assumption is that money is neutral in the long run. To understand the neutrality of money, one should differentiate between the determinants of relative prices and determinants of the general price level. The former is determined by real supply and demand while the latter by the supply of and demand for money. To keep the relative prices unchanged, the homogeneity of the system requires any change in nominal prices to be unit proportional to the change in the money supply. Alternatively, the change in the general price level would cause exchange rates to change such that the relative price of domestic and foreign goods remains unchanged, which is often referred to as purchasing power parity. The combination of these two properties explains the neutrality of money concerning the relative prices (Frankel 1984).

The second assumption is that changes in nominal money, in the short run, lead to changes in relative prices. The general price index includes both flexible and fixed price goods. Therefore, the general price level cannot freely and fully respond to monetary changes in the short run. So, changes in the nominal money supply can be interpreted as changes in the real money supply which will induce changes in the real interest rates and consequently relative prices (Frankel 1984). The last assumption is that overshooting happens in case some markets adjust slower to the shocks. The flexible prices move more than proportionate to compensate the sluggish adjustment of other prices when there is a monetary change (Bordo 1980; Barnett, Bessler, and Thompson 1983; and Frankel 1984).

Review of Previous Works

Neutrality of money, in the long run, is widely accepted among macroeconomists. In the short run, however, the key determinants and the extent of the impact of money supply on relative prices are subject to discussion. The drastic behavior of nominal agricultural prices in the 1970s and 1980s, and again in 2000s and 2010s, has been the focal point of the arguments by scholars. Two distinct explanations have emerged in the literature and evolved during the past decades. The empirical methods used to evidence the theoretical explanations have also improved as well. In this chapter, we will review a set of exemplary works that represent such theoretical and empirical progress in this literature. Since the early works of Cairnes, "traditional" and "monetarist" explanations are the two alternative clarifications for the behavior of the prices in response to a macroeconomic shock. While we would have a glimpse of the related works to the former approach, the focus of our study is on the latter one.

The traditional approach stresses the structural factors as the cause of real shocks in the commodity prices. Money supply change, later, validates or accommodates these shocks and thus takes a passive role (Barret, Bessler, and Thompson 1983). In this view, the impact of institutional and technological change on the short-run elasticity of supply varies across the markets. Consequently, prices in various markets would respond differently to the monetary shocks.

While the earlier works in this literature have focused on the demand-side explanation for the commodity price variation[6], Borensztein and Reinhart (1994) expanded the traditional approach in two different ways. They improved the supply-side explanation

---

[6] See, for instance, Chu and Morrison (1984) and Gilbert (1989).

through accounting for the supply of commodities by the emerging economies and then measuring the impact of commodity exports on the prices. They also broadened the demand-side explanation by including developing countries in their structural estimations. Their empirical results confirmed both aspects of their extension. They conclude that the supply shocks were the key factor in explaining the commodity price volatility in the 1970s and 1980s. It is important to note that in the traditional approach, either demand-side or supply-side explanation, the money supply has a passive role.

The alternative explanation for the commodity price changes in response to macroeconomic shocks emphasizes the active role of monetary policy. In this view, authorities could affect real prices by proactively changing the money supply. The pattern of price response, however, depends on price flexibility. Bordo (1980) argues that the degree of price flexibility across industries implicitly depends on the length of contracts which itself depends on the price variability in that industry. In his view, higher price variability leads to shorter contracts (more flexible prices) and, consequently, faster price response to shocks. To test this hypothesis empirically, he measures the effect of the monetary change on the prices at industry and sectoral level by regressing changes in prices on current and past changes in money. His theoretical and empirical results confirm the traditional price adjustment pattern that raw commodities respond more rapidly than manufactured goods.

The empirical evidence on whether the role of monetary policy is active or passive in agricultural price movements depends on the method and the data used in each study. While structural econometrics can only confirm the statistical relationships between monetary phenomena and agricultural prices, they lack the power to identify causality.

Barnett, Bessler, and Thompson (1983) used Granger method to test the direction of causality between the U.S. money supply and nominal agricultural prices. Using monthly observations from 1970 to 1978, they conclude that U.S. monetary policy had a significant causal effect on the price spikes in food and agricultural products during that period. Their empirical results are in line with a monetarist, rather that structuralist, explanation of the commodity price boom in the late 1970s.

In contrast to the prior decade, many commodity prices were falling during the 1980s. To explain the situation within a theoretical framework, Frankel (1984) draws links between international finance and agricultural sector using the model proposed by Dornbusch (1976), who showed that in the short run the exchange rate overshoots its long-run equilibrium. Frankel (1984) argues that both financial and agricultural markets are highly efficient and very similar in behavior. Thus, we could borrow the key concepts from the former market to explain price determinants in the latter. First, he interprets the homogeneity and purchasing power parity properties as the indication of money neutrality concerning relative prices. Then, he reminds that the interest rate parity and rational expectations are suggesting the efficiency in the market.

Finally, he calls the more-than-proportionate response of exchange rates to the money supply as the magnification effect. Using these concepts, he adapts the overshooting model to explain the changes in agricultural prices. In his explanation, the decrease in the money supply in the early 1980s would discourage investors from storable commodities. In the short run, the backward shift in demand would cause a decline in commodity prices, but the response would be more than proportionate, i.e., prices overshoot their long-run equilibrium. Thus, plummeting agricultural prices in the 1980s can be attributed to the continual rise in real interest rates at that time.

To test whether findings by Cairnes and Bordo apply to various time periods, Devadoss and Meyers (1987) employ vector autoregression (VAR) method to a set of monthly data for 1960 through 1985 and test the dynamic response of agricultural prices to money supply shocks. According to their empirical results, agricultural prices show faster adjustment speed compared to industrial prices which is a confirmation of previous works. They conclude that since money is found non-neutral in the short run, a positive (negative) shock could benefit (harm) farmers because farm prices tend to increase (decrease) relatively more than nonfarm prices. It is noteworthy that U.S. monetary policy during the post-World War II have been steady and the economy has been fairly stable. Thus, the impact of a positive money supply shocks would be in favor of the agricultural sector (Devadoss and Meyers 1987).

A standard VAR system is commonly used in analyzing the effect of money supply on commodity prices in the United States. Anzuini, Lombardi, and Pagano (2013) employ this method to a large set of monthly variables from 1970 to 2008. They conclude that expansionary monetary policy was a driver for the commodity prices to rise in this period; however, the direct impact was not large. While Granger causality and VAR models could elucidate the relationship between variables, one could argue that the estimated coefficients hardly represent a true causal link (Bessler and Lee 2002).

To investigate the direct and indirect causal links between variables, the alternative approach would use the directed graph method. Bessler and Lee (2002) applied this directed graph technique to investigate the relationship between money, income, the general level of prices, and wheat price in the U.S. for the 1869 to 1914 period. Perez and Siegler (2006) expanded their work to include 12 countries and fifteen more years in their analysis. In general, both studies find a strong causal link between money and prices in the period of their studies. More recently, empirical works apply Johansen's cointegration test and variations of the vector error correction model (VECM) to test the extent of overshooting by commodity prices. We will leave further discussion on the proper empirical methodology to test our theoretical hypothesis to Chapter six.

While VAR and VECM models can empirically test the short-term effect of the real interest rates, which represent monetary policy, on the commodity prices and directed graph methods clarify causal links between these variables, none of the approaches can explain the mechanisms through which monetary policy determine prices. Assuming that all commodities are storable, higher interest rates would increase the supply and consequently reduce the market price of commodities through increasing current extraction, decreasing inventories, and increasing demand for treasury bills (Frankel 2008).

The theoretical framework that can explain all three channels is adopted from Dornbusch (1976) who first developed the overshooting hypothesis to study the movement of exchange rates. He assumed an open economy in which good market prices adjust slowly to the innovations while asset markets adjustment quickly. In the short run, if the real output is fixed, the monetary expansion would lower interest rates which subsequently cause exchange rates to overshoot its long-run depreciation. A depreciation of the exchange rate reduces the relative price of the domestic goods, which implies increased excess demand, and gives rise to inflationary pressure. In the adjustment process, domestic good prices rise, interest rates increase, and exchange rates appreciate. Sluggish adjustment of good prices is the essential assumption in this analysis.

Frankel (1986a) applies the overshooting hypothesis proposed by Dornbusch to a closed economy to show that the exchange rate is not the only mechanism through which monetary policy impacts commodity prices. In his framework, Frankel replaces exchange rates with basic commodities which are distinct from manufactured goods. Commodities, similar to exchange rates, have flexible prices and adjust faster than manufactured goods with sticky prices. Since the adjustment speed is different, agricultural commodities overshoot their long-run equilibrium prices after a sudden change in the money supply.

Obstfeld (1986) argues that whether flexible prices overshoot is an empirical question and depends on the characteristics of the model used. Under certain conditions, overshooting would not occur even in the presence of sticky prices (Obstfeld 1986; Stamoulis and Rausser 1987). Whether the prices overshoot, however, is not as important. In fact, the overshooting hypothesis only explains the necessary conditions for monetary policies to have an impact on relative commodity prices (Stamoulis and Rausser 1987).

Saghaian, Reed, and Marchant (2002) expanded the model by assuming separate adjustment paths for two flexible prices in the economy, namely exchange rates, and agricultural prices. The main theoretical result from this study is that the burden of monetary shock is shared by the two flex-price sectors and therefore, the extent of agricultural price overshooting is lower when there are flexible exchange rates. However, the extent of overshooting in flex-price sectors depends on the weight of the sticky price sector in the price index. Recent movements toward deregulation of industries and increased competition among manufacturers and services would cause higher price flexibility in these sectors. Higher price flexibility in the overall price index implies higher stability and higher capability to absorb the shocks (Saghaian, Reed, and Marchant 2002).

In this study, we include the energy sector with its unique adjustment path. The main objective is to investigate the extent of overshooting in the flexible price sectors (exchange rates, agriculture, and energy) with and without biofuel policies. When biofuel policies are binding, specific price links between the energy sector and agriculture sector prevail that would affect the extent to which prices overshoot.

Recent R&D investment in biomass production has strengthened the linkages between agriculture and energy sectors. Economic and environmental factors that discourage fossil fuel consumption has significantly contributed to the rise in energy demand for agricultural products in the past decade. Hu *et al*. (2015) investigate the impact of energy policies on the agricultural prices in the short and long run. They include import taxes on fossil fuels and subsidies for biomass production to the overshooting model and compare their theoretical results for the different elasticity of substitution between agricultural products and bonds.

They found that import taxes on fossil fuels would negatively impact agricultural prices in the long run only if agricultural products and bonds are freely substituted. Otherwise, the impact is ambiguous. On the other hand, an increased subsidy for biomass production could decrease agricultural prices and exchange rates in the long run if the policy increases the net exports significantly. Else, the effect is uncertain. The short-run impact of the subsidy is, however, the rise in prices.

To improve their analytical framework, there are two important assumptions that should be relaxed. First is that they consider agricultural products as non-tradable goods.

Although this could be just a simplifying assumption, the reality in international trade is the opposite. Moreover, assuming tradeable agricultural products would not add complexity to the theoretical model. The other assumption to be relaxed is that biomass energy and fossil fuels are not substitutes. Therefore, when the import tax on fossil fuel is increased, they conclude that demand for total energy and thus biomass energy would decline. Consequently, agricultural prices decrease. However, such policy could increase the demand for biomass energy if we assume that it can substitute for fossil fuels. Thus, the demand for agricultural products to produce biomass would increase, which in turn increases the price. This possibility is also ignored in their analysis. We have relaxed both assumptions in our analytical framework which is explained in Chapter Four.

The robustness of the overshooting hypothesis has been investigated from different perspectives. Lai, Hu, and Wang (1996) found that under certain conditions agricultural prices may undershoot. First, they test the behavior of the prices following an anticipated monetary shock. Second, they relax the assumption that manufactured prices react sluggishly. In this case, agricultural prices undershoot at the time of policy announcement. Then, both agricultural and manufactured prices would rise before policy implementation and finally stay at their stationary level after the policy implementation. Lai, Hu, and Fan (2005) also reexamined the robustness of the hypothesis by testing various degrees of asset substitutability between agricultural commodities and bonds.

In a closed economy, when the degree of substitutability is high (low), their theoretical results confirm overshooting (undershooting) of agricultural prices. Using numerical simulations, they conclude that their results could apply to a model with an open economy. More recently, focusing only on the agricultural commodity market, Tai *et al.*

(2014) also find that agricultural spot prices may misadjust and undershoot when the time lag between policy announcement and implementation is short. When implementation time is longer, futures price falls at the time of announcement due to maladjustment of spot prices.

Theoretical and empirical results derived from the overshooting model has policy implications for the countries interested in stabilized commodity prices and farm income. Chen *et al*. (2013) suggest a theoretical approach that identifies the effective combination of policies on price stability within this framework. They extend the model proposed by Frankel (1986) to an open economy and also adopted the assumption of asset substitutability from Lai, Hu, and Fan (2005) to investigate the effectiveness of target zone policy in combination with various other strategies. They found that in response to shocks to agricultural markets, a target zone policy is most effective in stabilizing prices and nominal farm income when it is complemented by government purchasing programs but not by a price subsidy policy.

In this literature, theoretical findings have been tested empirically in the context of both developed and developing countries using alternative autoregressive methods. Rausser, Chalfant, and Stamoulis (1985) investigated the impact of monetary policy on agricultural prices when the U.S. economy was experiencing relatively higher interest rates and rapid appreciation of the currency, which depressed agricultural exports, plummeted prices and lead to a financial crisis in the agricultural sector. They used a food price index to represent flexible price market (and a non-food price index to represent fixed prices) and found a larger response to anticipated money growth by food inflation.

Taylor and Spriggs (1989) examined the importance of monetary policy on Canadian agricultural prices using vector autoregressive (VAR) modeling. They found U.S. monetary policy, reflected by the U.S./world exchange rate, to be the most significant on the instability of Canadian agricultural markets. Their empirical results confirm the overshooting hypothesis that agricultural prices respond faster to monetary shocks compared to manufactures prices.

Saghaian, Hasan, and Reed (2002) used a VECM/ VAR approach and graph theory to test the hypothesis for four Asian countries. They found evidence of larger overshooting for agricultural prices compared to manufactures in three of the countries[7] but could not confirm the neutrality of money in Indonesia, Korea, and Thailand. Awokuse (2005) also used the directed acyclic graphs (DAGs) approach to identify causal relationships between macroeconomic variables and relative prices. He, then, applied a vector error correction model (VECM) to test for cointegration between the economic series. He used monthly U.S. data from 1975 to 2000 in his study and found that rather than money supply, the exchange rate is the primary macroeconomic policy tool that impacts agricultural prices. He showed that exchange rates are directly linked to interest rates.

These empirical results imply a shift in Federal Reserves' policy from "money supply control" to "financial instruments adjustment" during the period of the study. The choice of a policy instrument that represents money supply (M1, M2 or another proxy for money stock) and the level of aggregation in prices could impact the empirical results. Using Johansen's cointegration test and VECM approach, Saghaian, Reed, and Hasan (2006) found a significant effect for money supply, and a less important role for exchange

---

[7] in Korea, Philippines, and Thailand

rates, on livestock-oriented commodity[8] prices. Livestock prices show the highest degree of overshooting, followed by crops and industrial prices, in response to changes in M1 while the response to M2 is larger for industrial prices.

Bamba, Reed, and Saghaian (2008) also used VECM approach to examine the links between the U.S. monetary policy and tropical commodity prices. They used monthly data on the price of coffee and cocoa in international markets and the M1 money stock in the United States for the period of 1995 to 2007. The empirical results suggest that in response to money supply shock, those prices undershoot in the short-run, which can be interpreted as a tax for the countries that rely on the income from trading coffee and cocoa. Therefore, changes in the U.S. monetary policy can transmit instability to developing countries through its effect on the commodity prices in the international markets.

More recently, Bakucs and Fertő (2013) examined the overshooting hypothesis in the context of a transition economy. They studied the impact of monetary policy in post-communism Hungary and found that long-run money neutrality does not hold in this economy. Therefore, monetary policy has a significant impact on agricultural markets both in the short-run and the long-run. Due to the lack of effective farm policy in the country, the instability of the farm income depends highly on market prices. So their results are very important for Hungary. They used Johanson’s cointegration and VECM approach in their empirical analysis where results confirm faster adjustment speed for agricultural prices and exchange rates in response to money supply changes.

Elevated commodity prices in the 2005-2008 period renewed attention to measuring the size of monetary policy impacts on individual commodity prices

---

[8] Corn, soybean, Broiler, Beef, and Pork

(Scrimgeour 2014). Access to high-frequency financial market data provides the opportunity to examine the response of commodity and asset markets to the monetary policy immediately after the announcements made by the Federal Open Markets Committee (FOMC). One would expect that the short-run impact of money surprises is larger than the longer horizon.

Scrimgeour (2014) tests whether commodity spot prices move more than future prices in response to unexpected money changes through an event study procedure. In this method, unlike the VAR approach, the price response is not restricted to the previous months' (quarters') policy. To measure the shock, Scrimgeour (2014) uses the spot month federal funds futures contract and switches to the next month's contract in case of the new policy announcement. In the empirical analysis, he uses daily spot prices for seventeen commodities[9] for the period of 1994 to 2008 and considers FOMC meeting dates as the event days. He found that the overall response of commodity prices to monetary shocks is substantial while the response of metals is larger than agricultural commodities and oil. He concludes that each percentage point decline in interest rates would increase commodity prices by 5 percent and therefore the monetary policy could not have generated a sustained increase in the prices in the 2000 – 2007 period.

This research is organized in five chapters. Chapter two reviews the energy policy and the impact of biofuel production on the agricultural sector in the United States. The links between the energy sector and the agricultural sector, through ethanol production, is the key factor in developing our theoretical model. Chapter three presents the theoretical model for this study. We extend the overshooting hypothesis by including the energy sector

---

[9] nine metals (gold, silver, copper, aluminum, tin, zinc, platinum, lead, and nickel), seven agricultural commodities (cocoa, coffee, cotton, wheat, hogs, live cattle, and livestock), and oil.

into the model and conclude that flexible energy prices partly absorb the impact of monetary shocks and share the burden with other flexible prices, including agricultural commodity prices and exchange rates. In Chapter four, the model is tested empirically using monthly data and a vector autoregressive framework. The results are compared to previous empirical findings to highlight the impact of including the energy sector in the model. Finally, in chapter five, the conclusions of this research are presented, and policy implications for theoretical and empirical results are discussed.

Chapter 2. Energy Policy in the United States

Introduction

Declining real energy prices for at least two centuries has been a major driver of U.S. economic growth, especially in the postwar period. The growth literature has neglected the constraints that energy availability and prices pose to the future growth of the country (Ayres *et al*. 2013). The interactive role of energy in the economy through its linkage to other sectors is critical to policy analysis (Hudson and Jorgensen 1974). Energy changes the state of the economy directly, through its impacts on the output, and indirectly, through affecting capital investment decisions (Cooper 1980).

The effect of energy shortages (energy price booms) on halting manufacturing outputs on the one hand and rising agricultural prices, on the other hand, are evident examples of the direct links. For instance, higher prices for petroleum-based energy commodities could shift the energy consumption composition in favor of renewable resources, namely biofuels, especially when the infrastructures are present. Increased demand for biomass feedstock, in turn, increases agricultural prices. More indirectly, higher energy prices hinder the demand for capital, in the long run, lowers the rates of return on investments and, therefore, decreases the rate of capital formation. Due to a lower rate of capital formation, the rate of substitution between capital and labor slows down, which results in lower rates of productivity growth, and ultimately lower rates of economic growth (Jorgenson 1978).

Many economists agree that higher energy prices, along with lower monetary growth, was a contributing factor to the U.S. recession in the mid-1970s and later in the early 1980s (Hudson and Jorgensen 1974; Jorgenson 1978; Cooper 1980; Hooker 1996).

The lower prices in the intervening years, however, did not have the equivalent opposite impact, due to the asymmetry between the effects of energy price increases and decreases (Dotsey and Reid 1992; Mork 1989; Shapiro and Watson 1988). Cunado and Perez de Gracia (2005) suggest that oil price shocks affect economic growth and inflation in the short-run, but the relationship is asymmetric in some countries.

Previous studies show that energy demand is price responsive in the U.S., although few empirical studies[10] reject the hypothesis that those responses are asymmetric and that oil prices are endogenous to the U.S. economy. Hamilton (1996) suggests that the mixed empirical results are mostly due to methodological differences. For instance, using a *net increase* in oil prices can better address market corrections for declines in previous periods. He empirically tests and confirms the asymmetry in the impact of oil price increases and decreases which is consistent with the fact that almost all U.S. recessions since the 1970s were preceded by oil shocks while the recovery due to declining prices was not as notable.

Kilian (2008) further discusses that the impact of a positive shock in energy prices primarily affects the economy through the reduction of spending on goods and services by firms and consumers. Higher energy prices increase the marginal cost of production and dampen the demand for the output, therefore forcing firms to adjust their investment decisions accordingly. The impact on consumers is expected to be through the impact on income, uncertainty, savings, and operating costs. According to Kilian (2008), the aggregate demand channel of transmission explains the asymmetric macroeconomic response to energy price shocks, though the asymmetry is more evident in the investment rather than consumption expenditure decisions.

---

[10] For example Hooker (1996) and Kilian (2008).

A disruption in the total spending on goods and services in the economy impacts the aggregate demand for energy. Industrial demand for energy depends on the underlying production structure of the economy and the cost share of energy as one of its inputs (Sorrell 2015; Fuss 1977). Whether energy can be substituted for other factors of production determines the energy demand response to price shocks (Pindyck 1979). There is less dispute on the substitutability of energy and labor in empirical work. Energy and capital, however, is reported to be complements in single-country studies (Fuss 1977; Berndt and Wood 1975; Hudson and Jorgensen 1974) but substitutes in the multi-country studies (Pindyck 1979; Griffin and Gregory 1976).[11] Nevertheless, energy price volatility is only one of the channels that may impact investment decisions. Sociotechnical systems including technology, institutions, and social behavior are also shaping individual preferences and decisions to a great degree (Sorrell 2015).

Energy policy is an integral part of the modern sociotechnical systems to control adversities of the uncertain energy market. The significant variability of petroleum prices in international markets and the constant decline in the returns for energy investments has redefined energy supply as a national security issue. Regulations were outlined as energy conservation and market liberalization attempts in earlier decades and as environmentally friendly efforts in recent years (Sorrel 2015). Since the 1970s, the focus of U.S. energy policy has changed from just assuring a secure low-cost supply of energy and reducing energy demand to addressing public health, global climate change, and environmental concerns (Yacobucci 2015).

---

[11] Pindyck (1979) suggests that complementary relationship between energy and capital is observed in the shorter run and substitutability in the longer run.

Many programs with different and sometimes contradicting objectives have influenced domestic energy prices and thus the demand for energy, through raising efficiency standards, enforcing reduced greenhouse gas emissions, and encouraging the transition to renewable energy (Ayres *et al*. 2013; Kilian and Vega 2011). The Clean Air Act of 1970 is the earliest legislation that had unintended (positive) consequences on the energy sector in the postwar era. While the central point of the policy was to reduce hazardous emissions, control air pollution in metropolitan areas, and address related public health risks, it certainly transformed the technology in the transportation system, power plants, and chemical plants.

Later in the 1980s and early 1990s, production and consumption of ethanol were encouraged by ensuring grants, loans, and other incentives to small producers. The Alternative Motor Fuels Act of 1988 and the Clean Air Act Amendment of 1990 established new fuel standards that increased the demand for ethanol as a substitute additive (Miranowski 2014). The Environmental Protection Agency (EPA) developed many programs, such as elimination of lead from gasoline, enforcing the use of reformulated gasoline in highly polluted metropolitan areas, encouraging the use of low sulfur fuels, and establishing a national renewable fuel (RF) program, which impacted energy markets during the past decades (U.S. EPA 2007). In recent years, policy tools that transfer benefits to consumers have changed from price controls to subsidy and taxation mechanisms through which consumption of non-fossil fuels are encouraged (Ayres et al. 2013). Perhaps, one of the most controversial features of energy policy in the U.S. is the mandates to increase the consumption of biofuels.

The Energy Policy Act of 2005 (EPAct 2005) and the Energy Independence and Security Act of 2007 (EISA) included comprehensive provisions in almost all aspects of energy policy. The primary emphasis of EPAct 2005 was "…to ensure jobs for our future with secure, affordable, and reliable energy…" and EISA intended "to move the United States toward greater energy independence and security, to increase the production of clean renewable fuels, to protect consumers, to increase the efficiency of products, buildings, and vehicles, to promote research on and deploy greenhouse gas capture and storage options, and to improve the energy performance of the Federal Government." To encourage the production of biofuels, Congress set the initial Renewable Fuels Standard (RFS) in the EPAct with a target of 7.5 billion gallons per year (bgy) of conventional ethanol by 2012, which was later raised to 36 bgy of biofuels by 2022 in EISA. The second mandate required only 15 bgy of conventional ethanol while the remaining 21 bgy should be covered by biodiesel and newer generations of biofuels (Miranowski 2014; Whistance and Thompson 2014; Roberts and Schlenker 2013).

Although RFS is defined as the minimum quantity of biofuel that should be consumed each year, we include it as the share of biofuel in total fuel consumption. The nature of interlinks between energy prices and agricultural prices (through the biofuel industry) impacts the variability of commodity prices, and therefore the adjustment path of agricultural prices would be different once we account for those links (Saghaian 2010).

U.S. Biofuel Policy

Biofuel policies are used to achieve energy, environmental and agricultural policy goals (de Gorter and Just 2010). However, the balance of trade and energy security are the most important policy standpoints. Policymakers in oil importing countries encourage domestic consumption of biofuels to replace gasoline, reduce the trade deficit, and secure a reliable supply of energy (Moschini, Lapan, and Kim 2017; Zilberman et al. 2014). To increase consumption of biofuels, mandates are imposed as both a subsidy on biofuel and a tax on total fuel consumption (de Gorter and Just 2010). Expansion of biofuel production indirectly lowers the price of fuel. In response to biofuel production, the major producers of fossil fuels, i.e., Organization for the Petroleum Exporting Countries (OPEC), could reduce their exports to raise oil prices and divert their production to meet their domestic energy needs. Higher oil prices reduce the demand for fossil fuels in importing countries, encouraging them to replace biofuels. If biofuel production sufficiently displaces fossil fuels, it is possible for these countries to export excess refined gasoline and diesel and improve their terms of trade (Hochman 2014).

To address climate change issues, advocates of renewable energy refer to the social welfare studies that show the best policy to mitigate adverse impacts of climate change while maximizing welfare is to incent energy producers to pay for the externalities, which ultimately results in increased production of biofuels (Zilberman et al. 2014). In practice, whether the biofuel policy results in the reduction of CO2 emissions highly depends on the ratio of emissions from different fuels and the price responsiveness of the producers (de Gorter and Just 2010). Furthermore, limited agricultural land in many regions amplifies the adverse environmental impacts of the expansion of biofuel production (Naylor et al. 2007).

Currently, the main driver of profits in the biofuel industry is the governmental income transfer to the producers and distributors of the biofuels. The agricultural sector also benefits from the income transfer through the programs that support the production of various feedstocks. The Agricultural Act of 2014 provides education, research, and financial assistance programs to encourage investments in alternative energy technology and production of renewable biomass for biofuels and production of biobased products (U.S. House 2014).

The biofuel industry became profitable through government support. Ethanol production in the U.S. started to receive subsidies through the National Energy Act of 1978 (NEA78), which provided a tax exemption equivalent to 40 cents per gallon of ethanol. Although the form of the subsidy has changed throughout the years, it always remained between 40 to 60 cents per gallon (Tyner and Taheripour 2007). Currently, biofuel refineries are less dependent on subsidies and more competitive in the energy market (Babcock 2013). Both the energy content of ethanol as a substitute fuel and its oxygenation quality create value which incentives the refineries to continue producing and blending ethanol into transportation fuel, even in the absence of subsidies (Chen and Khanna 2012; Tyner and Taheripour 2007).

The combination of consumption subsidies in the form of blenders' tax credits, import tariff and duty on (sugarcane) ethanol, and blending mandates has been at the core of U.S. biofuel policy (Naylor et al. 2007). The Volumetric Ethanol Excise Tax Credit (VEETC) of \$0.12 per liter was established in 2005 but phased out in 2012. Tariffs on sugarcane ethanol consist of a specific tariff of \$0.14 per liter (\$0.54 per gallon) plus a 2.5% ad valorem tax. Similar to the tax credit, the specific tariff expired at the end of 2011 (Whistance and Thompson 2014; Roberts and Schlenker 2013; Chen and Khanna 2012). Introducing several policy tools may increase the diversity of the program and expand its target groups, but it might also have reverse consequences due to the complexity of the interaction of these policies (de Gorter and Just 2010). Currently, the mandates are the main factor that impacts the biofuel markets.

The mandates, defined by RFS, require a certain amount of renewable fuel to be blended into the U.S. transportation fuel supply. The most recent RFS requirements were laid out in EISA as a hierarchical set of scheduled quantitative minimum requirements for different types of biofuels from 2007 to 2022 (Moschini, Lapan, and Kim 2017; Whistance and Thompson 2014). Mandates are enforced by the EPA annually through the Renewable Identification Number (RIN) which is assigned to each gallon of biofuel produced or imported. Importers and refiners of fossil fuels[12] follow their renewable volume obligations (RVOs) calculated by the EPA.

RVOs are the fractional requirements that each party needs to follow, given their sales of transportation fuels. In fact, these fractional requirements define the volume of renewable fuel that must be blended into each gallon of the fossil fuel that is marketed. The RVOs are enforced through the RIN system. If an obligated party is unable to meet its RVO, it can choose to buy RIN in the market or carry a deficit forward for only one year (Moschini, Lapan, and Kim 2017; Whistance and Thompson 2014; Miranowski 2014).

Whether the biofuel policy (mandate and tax credits) reduce the consumption of fossil fuels depends on whether or not the policy is binding. The biofuel mandate is binding if the equilibrium quantity of biofuel use in the absence of the mandate is less than the amount required by the RFS. This market condition is expected when ethanol is not competitive with fossil fuels due to low crude oil prices or high corn prices (Whistance and Thompson 2014). However, if biofuels are profitable at the current energy prices, the

---

[12] “Obligated Parties” in the legislators’ language.

equilibrium quantity exceeds the RFS requirements, and the mandate is non-binding. In this case, ethanol prices can freely move in response to the gasoline prices (Whistance and Thompson 2014; Baffes and Haniotis 2010).

de Gorter and Just (2010) examine the impact of different biofuel policy on fuel consumption. They show that if when biofuel mandate is binding, and the price of gasoline is considered to be fixed, gasoline consumption is reduced and partially replaced by the mandated ethanol consumption but total fuel consumption declines. Tax credits have a similar impact on gasoline and ethanol consumption but an ambiguous impact on total fuel consumption. If gasoline prices are not fixed (endogenous), then gasoline consumption is lower than the previous scenario when mandates are binding, but total fuel consumption might increase or decrease depending on the price of blended fuel. Tax credits, however, reduce fuel prices and increase total fuel consumption in this scenario.

The Interconnections of Agriculture and Energy Markets

Energy markets affect agricultural prices through several channels. First, energy in the form of liquid fuel is an important input in the agricultural production process and pre- and post-harvest services. Also, the process of producing fertilizers is heavily energy dependent (Hertel and Beckman 2012; Naylor *et al*. 2007). Higher energy prices raise production costs and therefore negatively impact total agricultural production. Conversely, a biofuel policy that increases ethanol demand partially offsets the loss in agricultural production caused by the rise in energy prices (Timilsina, Mevel, and Shrestha 2011).

Second, crops are the main feedstock for biofuel production, and therefore any substantial change in the biofuel market would consequently affect the agricultural sector through the land use change and reduced supply of commodities for food. The expansion of biofuel processing plants affects the livestock sector by raising competition over feedstocks (Hochman 2014; Baffes 2013). For instance, Timilsina, Mevel, and Shrestha (2011) report that in response to higher oil prices, production of corn and sugar increase, while more energy intensive productions like livestock, fruits and vegetables, and rice would decline. Finally, higher energy prices affect the economy as a whole and its subsectors, including agriculture (Hochman 2014; Baffes 2013; Naylor *et al*. 2007).

The combination of higher crude oil prices, the fixed federal subsidy for ethanol production, and import restrictions on ethanol have created a profitable market for biofuels, putting upward pressure on demand for corn. Furthermore, the ban on MTBE[13] formed the secondary market for ethanol as the fuel additive which further increased demand for corn (Hochman 2014; Hochman, Rajagopal, and Zilberman 2011). As the price of crude oil increases, the impact of biofuels on corn prices become stronger (Roberts and Schlenker 2013; Tyner and Taheripour 2007).

Ethanol use is restricted by the blend wall, the maximum amount of ethanol that could be blended into the transportation fuel due to inadequate distribution infrastructure and the fuel system technology in the U.S. (Tyner 2010). Therefore, the size of the market for biofuels is defined by the mandates and the blend wall[14] (Zilberman *et al*. 2014; McPhail and Babcock 2012). In future, we expect improvements in technology in the transportation system and the expansion of the flex-fueled engines will shift the blend wall which will allow further expansion of the biofuel market. Technology improvements also

---

[13] Methyl tertiary butyl ether (MTBE) used to be added to gasoline to improve oxygenation. In 2006 MTBE was banned and ethanol took over the entire market for oxygenator/octane enhancers in gasoline (Hertel and Beckman 2012).

[14] The percentage of the biofuel blend in the transportation fuel which depends on policy and infrastructure.

increase the substitutability between fuels and strengthen the links between oil and biofuel markets (Timilsina, Mevel, and Shrestha 2011).

Biofuel policies impact various groups in the economy, including the transportation, fossil fuel, renewable energy, and agricultural industries, along with consumers (Zilberman et al. 2014). Creating a significant demand for biofuel feedstock changes the relative return to land in favor of biofuel crops which will induce land use change (Timilsina, Mevel, and Shrestha 2011). The immediate impact of biofuel mandates is to divert large amounts of corn and soybean oil to biofuel production and therefore improve farm income by increasing corn and soybean prices (Moschini, Lapan, and Kim 2017).

As this agro-energy link shifts the land use dynamics toward the production of biofuel crops, it puts upward pressure on land values. Hence, fewer resources are allocated to produce food, and global food supply falls which raises the price of food (Timilsina, Mevel, and Shrestha 2011; Rathmann, Szklo, and Schaeffer 2010; Elobeid *et al*. 2007). Increased price of feedstock and non-feedstock commodities due to biofuel policies in the U.S., Brazil, and E.U. has significant implications for developing countries. The benefit of higher commodity prices are to producers and the owners of land and labor; while consumers lose the most (Huang *et al*. 2012).

Ethanol production capacity has increased significantly in the United States, and consequently, corn prices and the value of corn exports has almost doubled (Zilberman *et al*. 2014; Tyner and Taheripour 2007). Roberts and Schlenker (2013) estimate that almost one-third of the U.S. corn production was shifted to biofuel industry to meet the 2009 mandates, which require 11 billion gallons (bg) of ethanol to be blended in gasoline.

Nevertheless, the price floor for feedstock crops, created by the energy prices, is significantly more important than the total quantity that is turned into biofuels (Baffes and Haniotis 2010).

The Impact of Biofuel Policies on Agricultural Prices

Co-movement of energy and agricultural prices is evidence for the impact of biofuel policy on agricultural prices (Gilbert 2010). It is important to note that whether the strong correlation between energy and commodity prices establish a causal link is an empirical question (Saghaian 2010). There is empirical evidence that shows the link between energy prices and non-energy prices is stronger in recent years (Baffes and Haniotis 2010). Since 2006, higher gasoline prices linked ethanol and crude oil markets, and the ethanol market established a link between crude oil prices and corn prices (de Gorter, *et al*. 2013; Hertel and Beckman 2012; Tyner 2010).

Saghaian (2010) concludes that national and international grain markets are dramatically affected by the economics of ethanol production. de Gorter *et al*. (2013) suggest that biofuel policies were the major cause of grain and oilseed price elevations in the past decade. The strong correlation between energy and agricultural prices is empirically confirmed by Myers *et al*. (2014), but only for the short-run. The implication of the temporary links between energy and agricultural markets is important for our study since the overshooting hypothesis examines the adjustment path of prices in the short-run. In the long-run, agricultural prices are determined by the structural supply and demand factors (Myers *et al*. 2014). There are some other studies that do not find a significant linkage between the two markets and therefore conclude a modest contribution of biofuels to the commodity price spikes (Mueller, Anderson, and Wallington 2011). However, higher commodity price instability should be of more concern rather than higher prices (Saghaian *et al*. 2018).

Recent literature mostly focuses on the transmission of price volatility between commodity and energy markets. Saghaian *et al*. (2018) investigated whether the price volatility transmission from the energy to the agricultural market and vice versa is symmetrical. They found that oil prices impact ethanol prices while ethanol and corn markets affect each other. Furthermore, they found that the nature of these effects are asymmetrical such that the volatility in ethanol and corn prices change differ in response to a positive or negative change in prices.

The asymmetric coordination between agricultural and energy markets also depends on what energy policy is binding. For instance, binding mandates and the blend wall both destabilize commodity markets, albeit in low and high oil price instances, respectively (Hertel and Beckman 2012). The empirical results on the extent and direction of volatility transmission are mixed. According to Saghaian *et al*. (2018), data frequency, the study period, model specification, countries under the study, and the combination of specific prices used to cause different results in empirical studies that examine the volatility spill-over between these markets.

Understanding the dominant price link between energy and commodities is essential when studying price volatility in agricultural markets. Ethanol mandates and the blend wall reduce the elasticity of demand for corn. Thus, biofuel policy is expected to reduce the transmission of energy price volatility into the crop sector. However, it increases crop price variability in response to supply-side shocks (Hertel and Beckman 2012; McPhail and Babcock 2012). In the next chapter, we will account for energy-agriculture links to examine the impact of biofuel policy on commodity price change in response to macroeconomic shocks.

Various programs encourage biofuel production, but the *blend mandate* is the most important policy in the United States which provides a guaranteed market by setting a minimum share of biofuel required in total fuel consumption. When energy policies are not binding, market forces determine energy prices. In this case energy prices partially absorb the effect of shocks and reduce commodity price volatility in response to monetary uncertainty (McPhail and Babcock 2012). When the blend mandate is binding, the long-run ethanol-gasoline price relationship weakens, and ethanol is priced on corn (Whistance and Thompson 2014; Tyner 2010).

Ethanol and gasoline are key inputs to the transportation fuel product and can be either complements or substitutes. When gasoline blendstock is more expensive than ethanol, blenders use ethanol as a substitute product which creates a strong positive correlation between prices. If mandates are binding and ethanol is more expensive, then blenders view the two products as complements and the consumer fuel price is the weighted average of ethanol and gasoline. Gasoline and implied ethanol prices at the retail level have a strong relationship, regardless of whether mandates are binding or not (Whistance and Thompson 2014; de Gorter and Just 2010).

Chapter 3. The Impact of Biofuel Policies on Overshooting of Agricultural Prices: Theoretical Framework

Introduction

The impact of monetary expansion on agricultural prices is direct and consistent over time. However, the channels through which monetary policy affects commodity prices may change as institutions evolve (Gilbert 2010). In this chapter, we show how accounting for the energy sector changes the response of agricultural commodity prices to macroeconomic policy innovations. To do so, we extend Saghaian, Reed, and Marchant (2002) by including the energy sector in the overshooting model. In this model, the price of energy changes through a Walrasian adjustment mechanism which assumes that excess demand in the market motivates price changes (Nicholson 1978).

We solve the model in two scenarios. First, a price index for energy is considered endogenous to the model which has a unique dynamic adjustment path to a monetary shock. We do not include biofuel policy in this scenario. Second, we assume that the demand for energy is met by the supply of a) biomass energy, produced from agricultural feedstock; and b) other types of energy, mostly hydrocarbon energy. In this scenario, we consider a non-zero share for biofuel even in the absence of any binding policy, because blenders use ethanol as an octane enhancer in the transportation fuel. Otherwise, the binding policy creates minimum demand for biofuels. To represent the demand for feedstock to produce biofuels, we include the appropriate links between agricultural and energy prices in the model.

The Theoretical Model – Basic Scenario

Following Saghaian, Reed, and Marchant (2002), we assume rational expectations and perfect foresight in a small open economy. We also assume perfect capital mobility which implies uncovered interest parity and perfectly substitutable domestic and foreign bonds as the arbitrage condition. In this economy, domestic and imported outputs are imperfect substitutes and energy products, agricultural goods, and manufacturers are tradable. To simplify the economy and solve for the variables without entangling in the complexity of the interrelations between economic sectors, we assume the following four distinct markets with separate adjustment paths: a) agricultural sector; b) exchange rates; c) energy sector; and d) manufactures and services. The first three markets have flexible prices that adjust quickly to monetary policy shocks, but manufacturers' fixed prices adjust sluggishly. Finally, we assume that the total output, supply of manufacturing, fossil fuel energy, and agricultural commodities are fixed and equal to zero in the differential form. All variables are in logarithm in this model.

To represent the equilibrium in the money market, we specify the LM curve as equation (1) in which m is the exogenous domestic (nominal) money supply; p is the endogenous domestic price level; y is the exogenous domestic real output. The parameters χ (Chi) and λ (Lambda) denote income and interest response to money demand, respectively (χ, $\lambda > 0$).

$$m - p = \chi y - \lambda r \tag{1}$$

The consumer price index, p, is the weighted average of price of four sectors in this model where the share of each sector is the respective weight. The consumer price components are the price of manufactures p_m; the price of agricultural commodities p_c; the index price of energy p_e; the exchange rate e; and the foreign price index of all imports p^* as the following

$$p = \alpha_1 p_m + \alpha_2 p_c + \alpha_3 p_e + \alpha_4(e + p^*) \tag{2}$$

The exchange rate and all prices are endogenous, except for the price of imports. The parameter α_i (Alpha) denotes the share of each sector in the consumer price with $\alpha_1 + \alpha_2 + \alpha_3 + \alpha_4 = 1$.

We can combine equation (1) and (2) to get

$$m - [\alpha_1 p_m + \alpha_2 p_c + \alpha_3 p_e + \alpha_4(e + p^*)] = \chi y - \lambda r \tag{3}$$

Exchange rate market

We assume that the domestic interest rate is equal to the world rate plus the expected depreciation. Thus, the uncovered interest parity assumption, which implies the perfect capital mobility, can be specified as equation (4), where r denotes the endogenous domestic (nominal) interest rate; r^* denotes the given foreign (nominal) interest rate; x denotes the expected rate of exchange depreciation.

$$r = r^* + x \tag{4}$$

Equation (5) shows that the expected rate of depreciation in the exchange rate is exactly equal to the actual rate of change which implies the rational expectation or perfect foresight. In this equation, e is the current exchange rate, measured as the domestic currency per unit of foreign currency.

$$x = \dot{e} \tag{5}$$

In this economy, wealth is reserved in two forms of a) domestic money; and b) bonds. Bonds are available in either domestic or foreign denominations which, considering equation (4) and (5) together, are assumed to be perfectly substitutable. The difference between the nominal returns on domestic and foreign bonds is equal to the expected change in the exchange rate, x. From equations (4) and (5) we have:

$$r = \dot{e} \tag{6}$$

Replacing equation (6) into equation (3) and accounting for the "small" country assumption that implies the foreign interest rate and foreign prices are given, i.e., $p^* = r^* = 0$, as well as fixed output, $y = 0$, we will have

$$m - \alpha_1 p_m - \alpha_2 p_c - \alpha_3 p_e - \alpha_4 e = -\lambda \dot{e} \tag{7}$$

Now, we assume that money supply is stationary. In other words, $m = \bar{m}$ i.e., m equals its long-run value. Also $x = \dot{e} = 0$ and therefore $r = r^*$ in the long run. So, equation (7) in the long run is

$$\bar{m} - \alpha_1 \bar{p}_m - \alpha_2 \bar{p}_c - \alpha_3 \bar{p}_e - \alpha_4 \bar{e} = 0 \tag{8}$$

where variables with bar are defined as long-run values. Subtracting equation (8) from equation (7) and solving for $\dot{e}$ would lead to

$$m - \bar{m} - \alpha_1 p_m + \alpha_1 \bar{p}_m - \alpha_2 p_c + \alpha_2 \bar{p}_c - \alpha_3 p_e + \alpha_3 \bar{p}_e - \alpha_4 e + \alpha_4 \bar{e} = -\lambda \dot{e}$$

$$\dot{e} = \frac{1}{\lambda}\{\alpha_1(p_m - \bar{p}_m) + \alpha_2(p_c - \bar{p}_c) + \alpha_3(p_e - \bar{p}_e) + \alpha_4(e - \bar{e})\} \tag{9}$$

Agricultural commodities market

Following the literature, the supply of the agricultural sector, A, is assumed to be fixed at its natural level[15]. To simplify the analysis, we abstract from the role of energy in the production cost of goods. The market clearing condition for the agricultural sector is shown in equation (10) where the supply of agriculture equals to demand.

$$A = \gamma_1(e + p^* - p_c) + \gamma_2(p_m - p_c) - \theta[r - \dot{p}] + \varphi y \tag{10}$$

---

[15] The factors that affect the commodity supply, including the technological improvements are mostly unobservable and thus it is common to assume an exogenous supply of commodities (Borensztein and Reinhart 1994).

where γ_i (Gamma) is the relative price response of the consumption demand; θ (Theta) is the expectation coefficient or the speed of adjustment for flexible-price goods; and φ (Phi) is the income response of commodities demand (γ_i, θ, $\varphi > 0$). Considering the normalization assumptions ($A = 0$, $y = 0$, and $p^* = r^* = 0$), use equation (2) and (6) to rewrite equation (10) as follows

$$0 = \gamma_1(e - p_c) + \gamma_2(p_m - p_c) - \theta[\dot{e} - \alpha_1\dot{p}_m - \alpha_2\dot{p}_c - \alpha_3\dot{p}_e - \alpha_4\dot{e}] \tag{11}$$

Substitute equation (9) into equation (11) and solve for $\dot{p}_c$

$$\begin{aligned}-\theta\alpha_2\dot{p}_c = {}& \gamma_1 e - (\gamma_1 + \gamma_2)p_c + \gamma_2 p_m \\ & - \frac{\theta(1-\alpha_4)}{\lambda}\{\alpha_1(p_m - \bar{p}_m) + \alpha_2(p_c - \bar{p}_c) + \alpha_3(p_e - \bar{p}_e) \\ & + \alpha_4(e - \bar{e})\} + \theta\alpha_1\dot{p}_m + \theta\alpha_3\dot{p}_e\end{aligned}$$

$$\begin{aligned}\dot{p}_c = \frac{-1}{\theta\alpha_2}\Bigg\{ & \left(\gamma_1 - \frac{\theta\alpha_4(1-\alpha_4)}{\lambda}\right)e + \frac{\theta\alpha_4(1-\alpha_4)}{\lambda}\bar{e} \\ & - \left(\gamma_1 + \gamma_2 + \frac{\theta\alpha_2(1-\alpha_4)}{\lambda}\right)p_c + \frac{\theta\alpha_2(1-\alpha_4)}{\lambda}\bar{p}_c \\ & + \left(\gamma_2 - \frac{\theta\alpha_1(1-\alpha_4)}{\lambda}\right)p_m + \frac{\theta\alpha_1(1-\alpha_4)}{\lambda}\bar{p}_m - \frac{\theta\alpha_3(1-\alpha_4)}{\lambda}p_e \\ & + \frac{\theta\alpha_3(1-\alpha_4)}{\lambda}\bar{p}_e\Bigg\} - \frac{\alpha_1}{\alpha_2}\dot{p}_m - \frac{\alpha_3}{\alpha_2}\dot{p}_b\end{aligned} \tag{12}$$

In the long-run, $\dot{p}_m = \dot{p}_c = \dot{p}_e = 0$, thus equation (12) would be

$$0 = \frac{-1}{\theta\alpha_2}\{\gamma_1\bar{e} - (\gamma_1 + \gamma_2)\bar{p}_c + \gamma_2\bar{p}_m\} \tag{13}$$

Subtracting equation (13) from equation (12) and simplifying, one would get equation (14) in terms of $\dot{p}_m$, $\dot{p}_c$, and $\dot{p}_e$.

$$\dot{p}_c = \frac{-1}{\theta\alpha_2}\left\{\left(\gamma_1 - \frac{\theta\alpha_4(1-\alpha_4)}{\lambda}\right)(e-\bar{e}) - \left(\gamma_1 + \gamma_2 + \frac{\theta\alpha_2(1-\alpha_4)}{\lambda}\right)(p_c - \bar{p}_c) + \left(\gamma_2 - \frac{\theta\alpha_1(1-\alpha_4)}{\lambda}\right)(p_m - \bar{p}_m) - \frac{\theta\alpha_3(1-\alpha_4)}{\lambda}(p_e - \bar{p}_e)\right\} - \frac{\alpha_1}{\alpha_2}\dot{p}_m - \frac{\alpha_3}{\alpha_2}\dot{p}_e \qquad (14)$$

Manufacturing market

We follow Saghaian, Reed, and Marchant (2002) to define the clearing condition for the manufacturing sector. In equation (15), we assume that the price of manufactures is fixed and adjusts sluggishly to excess demand. In this equation, y_m^d denotes the aggregate demand for manufactures; y_m^s is the fixed potential domestic output in manufactures; μ is the expected secular rate of inflation; and π (Pi) represents the speed of adjustment to excess demand for fixed price goods.

$$\dot{p}_m = \pi[y_m^d - y_m^s] + \mu \qquad (15a)$$

The aggregate demand for manufactures is specified in equation (16) as a function of the relative prices, the real interest rate, and the income where δ_i (Delta) denotes the relative price response of manufactures demand; σ (Sigma) is the interest response of the manufacturers demand; and η (Eta) represents the income response of manufactures demand (δ_i, σ, $\eta > 0$).

$$y_m^d = \delta_1(e + p^* - p_m) + \delta_2(p_c - p_m) - \sigma[r - \dot{p}] + \eta y \qquad (15b)$$

We can replace (15a) into (15b) and then simplify it by using equations (2), (6), and (9) along with the normalization assumptions (i.e., $y_m^s = 0$, $y = 0$, and $p^* = r^* = 0$) to get equation (16)

$$
\begin{aligned}
&(1-\sigma\pi\alpha_1)\dot{p}_m \\
&\quad = \pi\left[\left(\delta_1 - \frac{\sigma\alpha_4(1-\alpha_4)}{\lambda}\right)e + \frac{\sigma\alpha_4(1-\alpha_4)}{\lambda}\bar{e}\right. \\
&\quad - \left(\delta_1 + \delta_2 + \frac{\sigma\alpha_1(1-\alpha_4)}{\lambda}\right)p_m + \frac{\sigma\alpha_1(1-\alpha_4)}{\lambda}\bar{p}_m \\
&\quad + \left(\delta_2 - \frac{\sigma\alpha_2(1-\alpha_4)}{\lambda}\right)p_c + \frac{\sigma\alpha_2(1-\alpha_4)}{\lambda}\bar{p}_c - \frac{\sigma\alpha_3(1-\alpha_4)}{\lambda}p_e \\
&\quad \left. + \frac{\sigma\alpha_3(1-\alpha_4)}{\lambda}\bar{p}_e\right] + \sigma\pi\alpha_2\dot{p}_c + \sigma\pi\alpha_3\dot{p}_e + \mu
\end{aligned}
\tag{16}
$$

In the long run, there is no excess demand in equation (15a) which implies $y_m^d = \bar{y}_m^s$ and therefore, $\dot{p}_m = \dot{p}_c = \dot{p}_e = 0$. Thus equation (16) would, in the long run, turn to

$$
0 = \pi\{\delta_1\bar{e} - (\delta_1 + \delta_2)\bar{p}_m + \delta_2\bar{p}_c\} \tag{17}
$$

Now we can subtract equation (17) from equation (16) and solve for $\dot{p}_m$ to get equation (18) which is, similar to equation (14), in terms of $\dot{p}_m$, $\dot{p}_c$, and $\dot{p}_e$.

$$
\begin{aligned}
\dot{p}_m = \frac{\pi}{(1-\sigma\pi\alpha_1)}&\left[\left(\delta_1 - \frac{\sigma\alpha_4(1-\alpha_4)}{\lambda}\right)(e-\bar{e})\right. \\
&- \left(\delta_1 + \delta_2 + \frac{\sigma\alpha_1(1-\alpha_4)}{\lambda}\right)(p_m - \bar{p}_m) \\
&\left. + \left(\delta_2 - \frac{\sigma\alpha_2(1-\alpha_4)}{\lambda}\right)(p_c - \bar{p}_c) - \frac{\sigma\alpha_3(1-\alpha_4)}{\lambda}(p_e - \bar{p}_e)\right] \\
&+ \frac{\sigma\pi\alpha_2}{(1-\sigma\pi\alpha_1)}\dot{p}_c + \frac{\sigma\pi\alpha_3}{(1-\sigma\pi\alpha_1)}\dot{p}_e + \frac{\mu}{(1-\sigma\pi\alpha_1)}
\end{aligned}
\tag{18}
$$

Energy market

There is empirical evidence that energy prices respond to macroeconomic news in the United States within a month or longer horizons (Kilian and Vega 2011). According to Frankel (2008), tight monetary policy reduces commodity prices, including energy products, through a) encouraging earlier extraction; b) decreasing inventories; and c) encouraging speculators to shift out of commodity contracts. Raw energy commodities are converted to marketable form before being used in economic activities, i.e., to produce goods and services (Medlock 2009a). However, there is no such thing as the energy market; rather it is used to refer to the fuel markets (Weyman-Jones 2009). To simplify our analysis, we assume that an aggregated fuel market represents the total consumption and supply of energy commodities. We assume that the change in the price of energy over time is given by equation (19a)

$$\dot{p}_e = \Phi[y_e^d - y_e^s] \tag{19a}$$

in which y_e^d and y_e^s are aggregate demand for and supply of energy, respectively, and Φ (Phi) denotes the speed of adjustment to excess demand in this sector. If we consider that the commercial consumption of energy is dominant in the market, then the aggregate demand for the energy is a function of relative prices, income (real output), and real interest rate. Decision to consume energy involves an investment decision at the household and firms level (Medlock 2009a). For instance, purchasing energy efficient appliances and machinery depends on the rate of return on these capital goods which in turn depends on real interest rates. When interest rates are low, investment on energy efficient goods increases and demand for energy services decreases. On the other hand, increasing interest rates will encourage current extraction of energy resources and increases the supply of energy, reduces the price and increases the demand (Medlock 2009b). Hence the demand for energy is a negative function of interest rates. The excess demand function is specified in equation (19b)

$$\dot{p}_e = \Phi[\beta_1(p_m - p_e) + \beta_2(p_c - p_e) + \tau y - \rho(r - p^{\cdot})] \tag{19b}$$

where β_i (Beta) is the relative price response of energy demand; Let $\rho = \rho^d - \rho^s$ where ρ^d and ρ^s (Rho) are the speed of adjustment for the energy demand and supply, respectively; and τ (Tau) is the income response of energy demand ($\Phi, \beta_i, \rho^d, \tau, \rho^s > 0$). We can simplify equation (19b) and Solve it for $\dot{p}_e$ using equations (2), (6), and (9) along with the normalization assumptions (i.e., $y = 0$ and $p^* = r^* = 0$). The result is as follows

$$\begin{aligned}(1-\rho\Phi\alpha_3)\dot{p}_e = \Phi\Bigg[&\left(\beta_1 - \frac{\rho\alpha_1(1-\alpha_4)}{\lambda}\right)p_m - \frac{\rho\alpha_1(1-\alpha_4)}{\lambda}\bar{p}_m \\ &+\left(\beta_2 - \frac{\rho\alpha_2(1-\alpha_4)}{\lambda}\right)p_c - \frac{\rho\alpha_2(1-\alpha_4)}{\lambda}\bar{p}_c \\ &-\left(\beta_1 + \beta_2 + \frac{\rho\alpha_3(1-\alpha_4)}{\lambda}\right)p_e - \frac{\sigma\alpha_3(1-\alpha_4)}{\lambda}\bar{p}_e \\ &-\frac{\rho\alpha_4(1-\alpha_4)}{\lambda}(e-\bar{e})\Bigg] + \rho\Phi\alpha_1\dot{p}_m + \rho\Phi\alpha_2\dot{p}_c\end{aligned} \tag{20}$$

In the long run, there is no excess demand in equation (19a) which implies $\dot{p}_m = \dot{p}_c = \dot{p}_e = 0$. Thus in the long run $\Phi[\beta_1\bar{p}_m + \beta_2\bar{p}_c - (\beta_1+\beta_2)\bar{p}_e] = 0$ which can be subtracted from (20) to get

$$\begin{aligned}\dot{p}_e = \frac{\Phi}{(1-\rho\Phi\alpha_3)}\Bigg[&\left(\beta_1 - \frac{\rho\alpha_1(1-\alpha_4)}{\lambda}\right)(p_m - \bar{p}_m) \\ &+\left(\beta_2 - \frac{\rho\alpha_2(1-\alpha_4)}{\lambda}\right)(p_c - \bar{p}_c) \\ &-\left(\beta_1 + \beta_2 + \frac{\rho\alpha_3(1-\alpha_4)}{\lambda}\right)(p_e - \bar{p}_e) - \frac{\rho\alpha_4(1-\alpha_4)}{\lambda}(e-\bar{e})\Bigg] \\ &+\frac{\rho\Phi\alpha_1}{(1-\rho\Phi\alpha_3)}\dot{p}_m + \frac{\rho\Phi\alpha_2}{(1-\rho\Phi\alpha_3)}\dot{p}_c\end{aligned} \tag{21}$$

Using the Cramer's rule, we solve equation (14), (18), and (21) for $\dot{p}_c$, $\dot{p}_m$, and $\dot{p}_e$. The result is the following set of equations in terms of parameters.

$$
\begin{aligned}
\dot{p}_c = \frac{-1}{\alpha_2}\Bigg[&\left(\pi\alpha_1\delta_1 + \frac{(1-\rho\Phi\alpha_3-\sigma\pi\alpha_1)}{\theta}\gamma_1 - \frac{\alpha_4(1-\alpha_4)(1-\sigma\pi\alpha_1)}{\lambda}\right)(e-\bar{e}) \\
&+\left(\Phi\alpha_3\beta_2 + \pi\alpha_1\delta_2 - \frac{(1-\rho\Phi\alpha_3-\sigma\pi\alpha_1)}{\theta}(\gamma_1+\gamma_2)\right. \\
&\left.-\frac{\alpha_2(1-\alpha_4)}{\lambda}\right)(p_c-\bar{p}_c) \\
&+\left(\Phi\alpha_3\beta_1 - \pi\alpha_1(\delta_1+\delta_1) + \frac{(1-\rho\Phi\alpha_3-\sigma\pi\alpha_1)}{\theta}\gamma_2\right. \\
&\left.-\frac{\alpha_1(1-\alpha_4)}{\lambda}\right)(p_m-\bar{p}_m) \\
&-\left(\Phi\alpha_3(\beta_1+\beta_2) + \frac{\alpha_3(1-\alpha_4)}{\lambda}\right)(p_e-\bar{p}_e)\Bigg] - \frac{\alpha_1}{\alpha_2}\mu
\end{aligned}
\tag{22}
$$

$$
\begin{aligned}
\dot{p}_m = \pi\Bigg[&\left(\delta_1 - \frac{\sigma}{\theta}\gamma_1\right)(e-\bar{e}) + \left(\delta_2 + \frac{\sigma}{\theta}(\gamma_1+\gamma_2)\right)(p_c-\bar{p}_c) \\
&-\left(\delta_1+\delta_2+\frac{\sigma}{\theta}\gamma_2\right)(p_m-\bar{p}_m)\Bigg] + \mu
\end{aligned}
\tag{23}
$$

$$
\begin{aligned}
\dot{p}_e = -\Phi\Bigg[&\frac{\rho}{\theta}\gamma_1(e-\bar{e}) - \left(\beta_2 + \frac{\rho}{\theta}(\gamma_1+\gamma_2)\right)(p_c-\bar{p}_c) \\
&-\left(\beta_1 - \frac{\rho}{\theta}\gamma_2\right)(p_m-\bar{p}_m) + (\beta_1+\beta_2)(p_e-\bar{p}_e)\Bigg]
\end{aligned}
\tag{24}
$$

Now we can express the system of equations (9), (22), (23) and (24) in a matrix notation as follows[16]

$$
\begin{bmatrix} \dot{e} \\ \dot{p}_c \\ \dot{p}_m \\ \dot{p}_e \end{bmatrix} = \begin{bmatrix} \Psi_1 & \Psi_2 & \Psi_3 & \Psi_4 \\ \Sigma_1 & \Sigma_2 & \Sigma_3 & \Sigma_4 \\ \Pi_1 & \Pi_2 & \Pi_3 & \Pi_4 \\ \Omega_1 & \Omega_2 & \Omega_3 & \Omega_4 \end{bmatrix} \times \begin{bmatrix} (e-\bar{e}) \\ (p_c-\bar{p}_c) \\ (p_m-\bar{p}_m) \\ (p_e-\bar{p}_e) \end{bmatrix} + \begin{bmatrix} 0 \\ -\dfrac{\alpha_1}{\alpha_2} \\ 1 \\ 0 \end{bmatrix}\mu
\tag{25}
$$

---

[16] See appendix A for details

The characteristic roots of (25) are the solutions ζ_1, ζ_2, ζ_3, and ζ_4 to the polynomial determinant $|Z - \zeta I| = 0$, where Z is the matrix in the system equation $\dot{X} = ZX$ of (25). Since we have assumed perfect foresight, the dynamic system in (25) is unstable and has a saddle point solution (Saghaian, Reed, and Marchant 2002). Assuming $-\zeta$ ($\zeta > 0$), is the negative characteristic root of the general solution for the expected future path of the variables in level form are

$$\begin{aligned}
&e(t) - \bar{e}(t) = exp(-\zeta t)[e(0) - \bar{e}(0)] \\
&p_c(t) - \bar{p}_c(t) = exp(-\zeta t)[p_c(0) - \bar{p}_c(0)] \\
&p_m(t) - \bar{p}_m(t) = exp(-\zeta t)[p_m(0) - \bar{p}_m(0)] \\
&p_e(t) - \bar{p}_e(t) = exp(-\zeta t)[p_e(0) - \bar{p}_e(0)]
\end{aligned} \tag{26}$$

In rate of change for (26), the equations would be

$$\begin{aligned}
&\dot{e} = -\zeta(e - \bar{e}) \\
&\dot{p}_c = -\zeta(p_c - \bar{p}_c) - \frac{\alpha_1}{\alpha_2}\mu \\
&\dot{p}_m = -\zeta(p_m - \bar{p}_m) + \mu \\
&\dot{p}_e = -\zeta(p_e - \bar{p}_e)
\end{aligned} \tag{27}$$

According to Dornbusch (1976), the monetary expansion would induce an immediate depreciation of spot exchange rate which in turn increase the excess demand. Consequently, inflationary pressure increases the domestic goods prices. On the other hand, positive change in money supply translates to lower interest rates and therefore capital outflow which further declines the exchange rate. The response of commodity prices in the adjustment period is more than proportionately, and they overshoot their long-run equilibrium (Saghaian, Reed, and Marchant 2002). Using equation (9) and the first line of equation (27) we can get

$$\dot{e} = \frac{1}{\lambda}\{\alpha_1(p_m - \bar{p}_m) + \alpha_2(p_c - \bar{p}_c) + \alpha_3(p_e - e) + \alpha_4(e - \bar{e})\} = -\zeta(e - \bar{e})$$

$$e = \bar{e} - \frac{1}{\alpha_4 + \lambda\zeta}[\alpha_1(p_m - \bar{p}_m) + \alpha_2(p_c - \bar{p}_c) + \alpha_3(p_e - \bar{p}_e)] \quad (28)$$

Equation (28) represents the relationship between the exchange rates and the price levels in other sectors of the economy. It implies that the extent which spot exchange rate deviates from its long-run equilibrium depends on the proportional deviation of manufacturing, agriculture and energy prices from their long-run equilibrium values considering the share of each sector in the price index. To obtain the impact of monetary expansion on the exchange rate, differentiate equation (29) with respect to money supply, m, and consider money neutrality in the long run (i.e., $d\bar{e} = d\bar{p}_c = d\bar{p}_m = d\bar{p}_e = dm$) along with short run stickiness of manufacturing prices (i.e., $dp_m/dm = 0$) to get:

$$\frac{de}{dm} = 1 + \frac{\alpha_1}{\alpha_4 + \lambda\zeta} - \frac{\alpha_2}{\alpha_4 + \lambda\zeta}\left[\frac{dp_c}{dm} - 1\right] - \frac{\alpha_3}{\alpha_4 + \lambda\zeta}\left[\frac{dp_e}{dm} - 1\right] \quad (29)$$

If we exclude the energy sector from the system, equation (29) would be identical to the equation (15) in Saghaian, Reed, and Marchant (2002). For the moment, let us assume money neutrality, in the short run, for both agriculture and energy sectors. It implies that $\frac{dp_c}{dm} = \frac{dp_e}{dm} = 1$ and therefore $\frac{de}{dm} = 1 + \frac{\alpha_1}{\alpha_4 + \lambda\zeta} > 1$ which indicates overshooting of the exchange rate in response to monetary expansion, similar to the results in Saghaian, Reed, and Marchant (2002). It is clear that the extent of the overshooting depends positively on the share of sticky price, and negatively on the share of other prices in the consumer price index. [17] It is also inversely related to the interest response of money demand, λ, and the speed of adjustment, ζ (Saghaian, Reed, and Marchant 2002). If we assume that there no

---

[17] One may consider $\alpha_4 = 1 - \alpha_1 - \alpha_2 - \alpha_3$ to facilitate the interpretation.

flexible price sectors in the economy (i.e., $\alpha_1 = 1$ and $\alpha_2 = \alpha_3 = \alpha_4 = 0$) then $\frac{de}{dm} = 1 + \frac{1}{\lambda\zeta}$ which is the same as Dornbusch (1976). On the other hand, if manufacturers adjust instantaneously to monetary innovations then $\frac{de}{dm} = 1$ and overshooting would not occur.

Now if we relax the assumption of money neutrality in flex price sectors, then both agricultural and energy prices can overshoot which means $\left[\frac{dp_c}{dm} - 1\right] > 0$ and $\left[\frac{dp_e}{dm} - 1\right] > 0$. In this case, monetary shocks may still induce the exchange rates to overshoot but the extent would be definitely less than before. Comparing this result with Saghaian, Reed, and Marchant (2002) reveals the role of the energy sector on sharing the burden of overshooting with other flexible-price sectors.

In case both agricultural prices and energy prices undershoot, i.e., $\left[\frac{dp_c}{dm} - 1\right] < 0$ and $\left[\frac{dp_e}{dm} - 1\right] < 0$, then the exchange rate will take all the burden of a monetary shock. The extent of exchange rate overshooting is bounded between the amount resulted from the previous two scenarios if only one sector overshoots and the other undershoots. Now if we solve equation (28) for p_c we can determine the extent of overshooting by the agricultural prices

$$p_c = \bar{p}_c - \frac{\alpha_1}{\alpha_2}(p_m - \bar{p}_m) - \frac{\alpha_3}{\alpha_2}(p_e - \bar{p}_e) - \frac{\alpha_4 + \lambda\zeta}{\alpha_2}(e - \bar{e}) \tag{30}$$

We can differentiate equation (30) with respect to money supply, m, and consider money neutrality in the long run (i.e., $d\bar{e} = dm = d\bar{p}_c = d\bar{p}_m = d\bar{p}_e$) along with short run stickiness of manufacturing prices (i.e., $dp_m/dm = 0$) to get

$$\frac{dp_c}{dm} = 1 + \frac{\alpha_1}{\alpha_2} - \frac{\alpha_3}{\alpha_2}\left[\frac{dp_e}{dm} - 1\right] - \frac{\alpha_4 + \lambda\zeta}{\alpha_2}\left[\frac{de}{dm} - 1\right] \tag{31}$$

Here, if we ignore the possibility of overshooting of the exchange rate and energy prices (i.e., $\left[\frac{de}{dm}-1\right]=\left[\frac{dp_e}{dm}-1\right]=0$), then $\frac{dp_c}{dm}=1+\frac{\alpha_1}{\alpha_2}$ which implies that in this situation the overshooting of agricultural prices depends on the weight of sticky-price sector in the price index relative to the agriculture sector, the same as described in Saghaian, Reed, and Marchant (2002). Agriculture price do not overshoot if manufactured price adjusts instantaneously to the monetary shocks.

If we allow the energy prices and the exchange rate to overshoot (i.e., $\left[\frac{de}{dm}-1\right]>0$ and $\left[\frac{dp_e}{dm}-1\right]>0$) then agricultural prices may still overshoot but the extent would be less than before. Therefore, the energy sector reduces the burden of the monetary shock on the agriculture sector by $\frac{\alpha_3}{\alpha_2}\left[\frac{dp_e}{dm}-1\right]$ which depends on the relative weights of energy to the agricultural sector in the price index. The last term on the right-hand side of equation (31) is $\frac{\alpha_4+\lambda\zeta}{\alpha_2}\left[\frac{de}{dm}-1\right]$ which implies that higher interest response for the money demand, λ, as well as higher adjustment speed, ζ, would also dampen the effect of monetary shocks on the agricultural prices. If, for any reason, energy price and the exchange rate undershoot (i.e., $\left[\frac{de}{dm}-1\right]<0$ and $\left[\frac{dp_e}{dm}-1\right]<0$), then agricultural price overshoots the most. The extent of agricultural price overshooting is less if only one of the energy price or exchange rate overshoot. Agricultural prices undershoot only if the negative terms in equation (31) are greater than the positive ones, i.e., $\left(\frac{\alpha_3}{\alpha_2}\left[\frac{dp_e}{dm}-1\right]+\frac{\alpha_4+\lambda\zeta}{\alpha_2}\left[\frac{de}{dm}-1\right]\right)>\left(1+\frac{\alpha_1}{\alpha_2}\right)$.

Similarly, if we solve equation (29) for p_e we can examine the overshooting of the energy prices. Equation (32) states that the deviation of energy prices from their long-run equilibrium depends on the deviation of the exchange rate and the other two prices from their respective long-run equilibrium.

$$p_e = \bar{p}_e - \frac{\alpha_1}{\alpha_3}(p_m - \bar{p}_m) - \frac{\alpha_2}{\alpha_3}(p_c - \bar{p}_c) - \frac{\alpha_4 + \lambda\zeta}{\alpha_3}(e - \bar{e}) \tag{32}$$

Again, assuming money neutrality in the long-run and stickiness of manufacturing prices we differentiate equation (32) with regard to the money supply to get the response of energy prices to monetary policy in the short run

$$\frac{dp_e}{dm} = 1 + \frac{\alpha_1}{\alpha_3} - \frac{\alpha_2}{\alpha_3}\left[\frac{dp_c}{dm} - 1\right] - \frac{\alpha_4 + \lambda\zeta}{\alpha_3}\left[\frac{de}{dm} - 1\right] \tag{33}$$

It is important to note that the dynamic adjustment path of energy prices is very similar to the agricultural prices. The extent of energy price overshooting is proportionate to the relative shares in the price index and negatively related to the interest response of the money demand, λ and the speed of adjustment, ζ.

The Theoretical Model – Biofuel Policy

To account for the role of biofuel policy on the adjustment path of agricultural prices in our model, we assume that the energy sector produces only two types of energy products, i.e., biomass and fossil energy. To simplify our analysis, we assume that the supply and demand of liquid fuel represent the energy market in the economy. Biofuel is blended into transportation fuel either as a substitute for fossil fuel or as an oxygenator, depending on crude oil prices. Thus, the total fuel consumed is a weighted average of biofuel and fossil fuel. Moschini, Lapan, and Kim (2017) show that the price of blended fuel is linked to the endogenous prices of fossil fuel input and renewable fuel. So, we define the price index for energy as a weighted average of the price for biofuel, p_b, and the price for fossil fuel, p_f, such that $p_e = \psi\ p_b + (1 - \psi)\ p_f$ where we use the share of biofuel in the total fuel consumption, ψ (Psi), as the weight.

The share of biofuel is limited at the lower bound by the renewable energy mandate ($\mathcal{M} \leq \psi < 1$) and is equal to the mandate ($\psi = \mathcal{M}$) when the mandate is binding[18]. Consumers value each type of fuel by its energy content, and therefore the willingness to pay for biofuel should be less than the fossil fuel, due to its lower energy content. Let ω (Omega) be the relative energy content of biofuel and fossil fuel such that $p_b = \omega p_f$ with $0 < \omega < 1$. So, we can specify the price index for energy in equation (34) to be proportionate to fossil fuel price

$$p_e = \psi\omega p_f + (1-\psi)p_f = (1+\psi\omega-\psi)p_f = \kappa p_f \tag{34}$$

where κ (Kappa) is $0 < \kappa < 1$ and decreasing in the share of biofuel in total fuel consumption. Using the new definition of energy price, the consumer price index in equation (2) would turn to the following

$$p = \alpha_1 p_m + \alpha_2 p_c + \alpha_3 \kappa p_f + \alpha_4(e + p^*) \tag{35}$$

Moreover, therefore the money market equilibrium is

$$m - \left[\alpha_1 p_m + \alpha_2 p_c + \alpha_3 \kappa p_f + \alpha_4(e + p^*)\right] = \chi y - \lambda r \tag{36}$$

Exchange rate market

Using equation (36) to solve equation (6) for $\dot{e}$, we get equation (40) which specifies the change of exchange rates over time as a function of prices deviate from their long-run equilibrium and the share of biofuel in the total fuel consumption.

---

[18] The technology in each country defines the upper bound of the biofuel blend in the transportation fuel which is called the blend wall. When there is an upper bond limit, the link between energy and agricultural markets disappear after energy prices reach a certain level. We abstract from this restriction in this analysis.

$$\dot{e} = \frac{1}{\lambda}\{\alpha_1(p_m - \bar{p}_m) + \alpha_2(p_c - \bar{p}_c) + \alpha_3\kappa\big(p_f - \bar{p}_f\big) + \alpha_4(e - \bar{e})\} \tag{40}$$

Agricultural commodities market

By imposing the biofuel policy, agricultural products now can be used as food and feed, biofuel feedstock, and commodity assets (Moschini, Lapan, and Kim 2017; Gilbert 2010). The demand for agricultural crops as an input to produce biofuel is negatively related to the price of crop and positively related to the price of biofuel. So, we include the relative price of biofuel (or its equivalent, i.e., ωp_f) to agricultural commodities to the right-hand side of the market equilibrium in equation (41) to represent the energy demand for agricultural commodities.

$$A = \gamma_1(e + p^* - p_c) + \gamma_2(p_m - p_c) + \gamma_3\big(\omega p_f - p_c\big) - \theta[r - \dot{p}] + \varphi y \tag{41}$$

We will use equation (35), (40), and same techniques as the previous section to simplify and solve equation (41) for $\dot{p}_c$ which will be in terms of $\dot{p}_m$ and $\dot{p}_f$.

$$\begin{aligned}\dot{p}_c = \frac{-1}{\theta\alpha_2}\Bigg\{&\left(\gamma_1 - \frac{\theta\alpha_4(1-\alpha_4)}{\lambda}\right)(e - \bar{e})\\ &- \left(\gamma_1 + \gamma_2 + \gamma_3 + \frac{\theta\alpha_2(1-\alpha_4)}{\lambda}\right)(p_c - \bar{p}_c)\\ &+ \left(\gamma_2 - \frac{\theta\alpha_1(1-\alpha_4)}{\lambda}\right)(p_m - \bar{p}_m)\\ &+ \left(\gamma_3\omega - \frac{\theta\alpha_3\kappa(1-\alpha_4)}{\lambda}\right)\big(p_f - \bar{p}_f\big)\Bigg\} - \frac{\alpha_1}{\alpha_2}\dot{p}_m - \frac{\alpha_3\kappa}{\alpha_2}\dot{p}_f\end{aligned} \tag{42}$$

Manufacturing market

Similar to the previous section, we substitute equation (16) into (15) to define the market clearing condition for the manufacturing sector. Then, using equation (35) and (40) we get the following in terms of $\dot{p}_m$, $\dot{p}_c$, and $\dot{p}_f$.

$$\dot{p}_m = \frac{\pi}{(1-\sigma\pi\alpha_1)}\Bigg[\left(\delta_1 - \frac{\sigma\alpha_4(1-\alpha_4)}{\lambda}\right)(e-\bar{e}) + \left(\delta_2 - \frac{\sigma\alpha_2(1-\alpha_4)}{\lambda}\right)(p_c - \bar{p}_c) - \left(\delta_1 + \delta_2 + \frac{\sigma\alpha_1(1-\alpha_4)}{\lambda}\right)(p_m - \bar{p}_m) - \frac{\sigma\alpha_3\kappa(1-\alpha_4)}{\lambda}\left(p_f - \bar{p}_f\right)\Bigg] + \frac{\sigma\pi\alpha_2}{(1-\sigma\pi\alpha_1)}\dot{p}_c + \frac{\sigma\pi\alpha_3\kappa}{(1-\sigma\pi\alpha_1)}\dot{p}_f + \frac{\mu}{(1-\sigma\pi\alpha_1)} \tag{43}$$

Energy Market

Similar to the previous section, we assume that the change in the price of the energy market in the short run is a function of excess demand in the market. To simplify our analysis, the liquid fuel market represents the energy market. Thus, similar to previous empirical studies (Moschini, Lapan, and Kim 2017; Drabik, Ciaian, and Pokrivčák 2016; McPhail and Babcock 2012) we assume that the aggregate demand for fuel is met by the supply of fossil fuel and biofuel. If the biofuel policy is not binding, energy (fuel) prices are determined by the market forces and therefore absorb some of the shocks to the commodity prices through the links that were created by biofuel production (McPhail and Babcock 2012).

We assume that the production demand for energy depends on the relative price of imports and energy. If imports are relatively less expensive, there is less willingness to produce at home, and therefore demand for energy would fall. Income is positively related to the demand for energy. Higher interest rates halt investment decisions, and thus the real interest rate is negatively related to the demand for energy. On the other hand, we assume that the supply of energy is positively related to the real interest rate. So, we consider $\rho =$

$\rho^d - \rho^s$ as the interest response of energy market where ρ^d and ρ^s are the speed of adjustment for the energy demand and supply, respectively. Supply of fossil fuel is considered as a function of the relative price of fossil fuel to biofuel while the supply of biofuel is defined as a function of the relative price of biofuel to agricultural commodities. Equation (44a) shows the change in the price of energy over time as a function of the excess demand where the definition of the parameters are similar to the previous section (Φ, β_i, ρ^d, τ, $\rho^s > 0$).

$$\dot{p}_e = \Phi\left[\beta_1(e + p^* - p_e) + \tau y - \rho(r - p^{\cdot}) - \beta_2\left(p_f - p_b\right) - \beta_3(p_c - p_b)\right] \tag{44a}$$

We use the price equivalents (i.e., $p_b = \omega p_f$ and $p_e = \kappa p_f$) and the normalization assumptions as before, to rewrite equation (44a) regarding fossil fuel.

$$\dot{p}_f = \frac{\Phi}{\kappa}\left[\beta_1\left(e - \kappa p_f\right) - \beta_2\left(p_f - \omega p_f\right) - \beta_3\left(p_c - \omega p_f\right) - \rho(r - p^{\cdot})\right] \tag{44b}$$

which is equivalent to the following equation when combined with equation (6), (35), and (40)

$$\begin{aligned}(1 - \rho\Phi\alpha_3)\dot{p}_f = \frac{\Phi}{\kappa}\Bigg[&\left(\beta_1 - \frac{\rho\alpha_4(1 - \alpha_4)}{\lambda}\right)(e - \bar{e}) \\ &- \left(\beta_3 + \frac{\rho\alpha_2(1 - \alpha_4)}{\lambda}\right)(p_c - \bar{p}_c) - \frac{\rho\alpha_1(1 - \alpha_4)}{\lambda}(p_m - \bar{p}_m) \\ &- \left(\kappa\beta_1 + (1 - \omega)\beta_2 - \omega\beta_3 + \frac{\rho\kappa\alpha_3(1 - \alpha_4)}{\lambda}\right)\left(p_f - \bar{p}_f\right)\Bigg] \\ &+ \frac{\rho\Phi\alpha_1}{\kappa}\dot{p}_m + \frac{\rho\Phi\alpha_2}{\kappa}\dot{p}_c\end{aligned} \tag{45}$$

After solving the set of equations (42), (43), and (45) for $\dot{p}_m$, $\dot{p}_c$, and $\dot{p}_f$, we form a system of equations that includes $\dot{e}$, $\dot{p}_c$, $\dot{p}_m$, and $\dot{p}_f$ in terms of just parameters. The difference with the system of equations in (25) is the last equation that denotes the change over time in the price of fuel (energy) as the following

$$\dot{p}_e = \frac{\Phi}{\kappa}\Bigg[\left(\beta_1 - \frac{\rho}{\theta}\gamma_1\right)(e-\bar{e}) - \left(\beta_3 - \frac{\rho}{\theta}(\gamma_1+\gamma_2)\right)(p_c-\bar{p}_c)$$

$$- \left(\frac{\rho}{\theta}\gamma_2\right)(p_m-\bar{p}_m) \tag{46}$$

$$- \left(\kappa\beta_1 + (1-\omega)\beta_2 - \omega\beta_3 + \frac{\rho\omega}{\theta}\gamma_3\right)(p_e-\bar{p}_e)\Bigg]$$

We express the system in a matrix notation[19]

$$\begin{bmatrix} \dot{e} \\ \dot{p}_c \\ \dot{p}_m \\ \dot{p}_f \end{bmatrix} = \begin{bmatrix} \Psi_1 & \Psi_2 & \Psi_3 & \Psi_4 \\ \Sigma_1 & \Sigma_2 & \Sigma_3 & \Sigma_4 \\ \Pi_1 & \Pi_2 & \Pi_3 & \Pi_4 \\ \Omega_1 & \Omega_2 & \Omega_3 & \Omega_4 \end{bmatrix} \times \begin{bmatrix} (e-\bar{e}) \\ (p_c-\bar{p}_c) \\ (p_m-\bar{p}_m) \\ (p_f-\bar{p}_f) \end{bmatrix} + \begin{bmatrix} 0 \\ -\dfrac{\alpha_1}{\alpha_2} \\ 1 \\ 0 \end{bmatrix}\mu \tag{47}$$

To focus on the stability of the system, we assume that the positive characteristic roots are equal to zero. Therefore the solution to the adjustment path exchange rates when $-\zeta$ ($\zeta > 0$) is the negative characteristic root, combined with equation (40), can be specified in rate-of-change form as the following

$$\dot{e} = \frac{1}{\lambda}\{\alpha_1(p_m-\bar{p}_m) + \alpha_2(p_c-\bar{p}_c) + \alpha_3\kappa(p_f-\bar{p}_f) + \alpha_4(e-\bar{e})\} = -\zeta(e-\bar{e})$$

Which gives us

$$e = \bar{e} - \frac{1}{\alpha_4+\lambda\zeta}\left[\alpha_1(p_m-\bar{p}_m) + \alpha_2(p_c-\bar{p}_c) + \alpha_3\kappa(p_f-\bar{p}_f)\right] \tag{48}$$

Assuming the money neutrality in the long-run along with short-run stickiness of manufacturing prices and using $\kappa = 1 + \psi\omega - \psi$, the impact of monetary expansion would be

$$\frac{de}{dm} = 1 + \frac{\alpha_1}{\alpha_4+\lambda\zeta} - \frac{\alpha_2}{\alpha_4+\lambda\zeta}\left[\frac{dp_c}{dm} - 1\right] - \frac{\alpha_3(1+\psi\omega-\psi)}{\alpha_4+\lambda\zeta}\left[\frac{dp_f}{dm} - 1\right] \tag{49}$$

---

[19] See appendix B for details

Equation (49) implies that higher shares of biofuel, ψ, in total fuel consumption would increase the extent of exchange rate overshooting, holding everything else constant. Note that due to the technical constraints in the short-run, the relative energy content of biofuel to fossil fuel, ω, is fixed and therefore κ is decreasing in ψ. It is clear from comparing the last term on the right-hand side of equation (29) and equation (49) that $\frac{\alpha_3}{\alpha_4+\lambda\zeta} > \frac{\alpha_3(1+\psi\omega-\psi)}{\alpha_4+\lambda\zeta}$ which implies that mandating biofuel consumption reduces the flexibility of the energy sector to share the burden of the monetary shocks with exchange rates and agricultural commodities.

However, the negative effect of biofuel mandate could be less important if the mandate remains at the current level of 10 to 15 percent. When the mandate is binding, $\psi = \mathcal{M}$ and, therefore, we can calculate $\kappa = 1 + \mathcal{M}\omega - \mathcal{M}$. For instance, if we assume a binding mandate equivalent to 15 percent biofuel in total fuel consumption, considering that a gallon of corn ethanol provides almost 70 percent energy of a gallon of gasoline, $\kappa = 1 + (0.15)(0.7) - 0.15 = 0.955$ which implies that the energy sector could be 4.5 percent less effective in absorbing the monetary shock compared to the case without biofuels.

If we rearrange equation (48) and solve it for p_c, then differentiate the result concerning a change in money supply, we can show how the biofuel policy may impact the overshooting of the agricultural prices.

$$\frac{dp_c}{dm} = 1 + \frac{\alpha_1}{\alpha_2} - \frac{\alpha_3(1+\psi\omega-\psi)}{\alpha_2}\left[\frac{dp_f}{dm} - 1\right] - \frac{\alpha_4+\lambda\zeta}{\alpha_2}\left[\frac{de}{dm} - 1\right] \tag{50}$$

Equation (50) shows that higher biofuel mandate dampens the shock absorbent quality of energy prices ($\frac{\alpha_3}{\alpha_4+\lambda\zeta} > \frac{\alpha_3(1+\psi\omega-\psi)}{\alpha_4+\lambda\zeta}$) and therefore agricultural prices may increase more than the previous case where biofuels were absent from the energy market. We can also solve the equation (48) for p_f and differentiate it with respect to the money supply to analyze the response of energy prices to monetary shocks when biofuel policy is in place. In this case, we will get

$$\frac{dp_f}{dm} = 1 + \frac{\alpha_1}{\alpha_3(1+\psi\omega-\psi)} - \frac{\alpha_2}{\alpha_3(1+\psi\omega-\psi)}\left[\frac{dp_c}{dm} - 1\right] - \frac{\alpha_4+\lambda\zeta}{\alpha_3(1+\psi\omega-\psi)}\left[\frac{de}{dm} - 1\right] \tag{51}$$

To compare equation (51) with equation (33) in the previous case, we can consider a situation where the energy prices overshoot the most, i.e., $\frac{dp_c}{dm} = \frac{de}{dm} = 1$. It is clear that $\frac{\alpha_1}{\alpha_3(1+\psi\omega-\psi)} > \frac{\alpha_1}{\alpha_3}$ which implies stronger response of energy prices to monetary innovations by introducing biofuels to the market.

Summary of Theoretical Results

We include the energy sector in the model to re-examine the overshooting of agricultural prices in response to a monetary shock. We assume that agricultural prices, energy prices, and the exchange rate adjust faster and manufacturing prices adjust relatively slower to the shock, and thus the impact of the shock is absorbed by the flexible prices in the model.

According to our theoretical model, if money is neutral in the short-run for agricultural and energy prices, the overshooting of the exchange rate decreases when the share of flexible prices in the consumer price index increases. This result implies that excluding energy prices form the model may result in overestimation of the extent of overshooting.

If we relax the assumption of money neutrality, then the impact of the monetary shock is distributed among all flexible prices, and they all may overshoot. The theoretical model shows that when energy prices and the exchange rate overshoot, agricultural prices may still overshoot but the extent is less than when energy prices are absent from the model. For example, comparing our theoretical results to Saghaian, Reed, and Marchant (2002) we conclude that in a similar situation, agricultural prices overshoot less in our model. The reason is that we expect the energy prices to share the burden of the shock with the other two flexible prices.

Agricultural prices overshoot the most when the exchange rate and the energy prices, undershoot. However, there is also a possibility in this model that agricultural prices undershoot their long-run equilibrium.

When biofuel policy is in effect, the extent of overshooting of the flexible prices depend positively on the share of biofuel from total fuel consumption. In other words, when the share of biofuel increases, the extent of overshooting of exchange rate and agricultural prices increases as well, all else constant. This result implies that higher biofuel mandates reduce the flexibility of energy prices and thus reduces their "shock absorbing" quality. In this case, the burden of the shock is only on the exchange rate and agricultural prices. Therefore, agricultural prices may increase more in the biofuel era compared to the prior time.

Chapter 4. The Impact of Biofuel Policies on Overshooting of Agricultural Prices: Empirical Evidence

Introduction

The theoretical model provides the foundation for the specification of the macroeconometric system in our empirical analysis. The system of equations in (25) denotes that the change of each endogenous variable over time depends on the deviation of all prices and exchange rate from their long-run equilibrium. However, the functional form in this system of equations is complex, and we cannot directly estimate and identify individual values for the parameters. To analyze the dynamic response of systems of interrelated time series to random shocks, the vector autoregression (VAR) methods are developed in the econometric literature. So, we follow the existing literature on the contemporary nonstationary time-series modeling. We examine the properties of the five univariate series and test for a possible long-run relationship among them. Then, we can estimate the parameters of a Vector Error Correction Model (VECM) and conduct hypothesis testing.

The overshooting hypothesis has been tested empirically by previous studies in various settings. Using the price index for each sector, the hypothesis is tested for advanced (Saghaian, Reed, and Marchant 2002; Taylor and Spriggs 1989) and transition economies (Bakucs and Fertő 2013; Saghaian, Hasan, Reed). The results imply faster speed of adjustment for agricultural prices than industrial prices in response to monetary innovations. Similarly, individual commodity prices respond faster than manufacturing prices (Saghaian, Reed, Hasan 2006; Bamba, Reed, Saghaian 2008). The slower adjustment speed for industrial prices is the key determinant of the impact that the macroeconomy has on the relative prices in the short-run. However, previous empirical studies did not find evidence of money neutrality in the long-run. Similar results were obtained from studies using VAR-alternative methods like Directed acyclic graph (DAG) theory (Awokuse 2005). Nevertheless, no previous study has included energy as an independent sector in the model. Therefore, we expand previous empirical studies by testing the overshooting hypothesis when energy prices have an independent dynamic adjustment path in the model.

Methods and Data

We use monthly time series data from 1975:1 to 2017:12 for the price of agricultural commodities $\{p_c\}$, price of energy $\{p_e\}$, manufacturing price $\{p_m\}$, exchange rate $\{e\}$, and the money supply $\{m\}$. We obtain all series from the Federal Reserve Economic Data (FRED) system. Table 1 presents the descriptive statistics of the variables used in the empirical analysis.

<< Table. 1 >>

To examine whether the natural logarithm of observed values for each series is stationary, we use Phillips-Perron (PP) test with the null hypothesis that each series has a unit root. We also use Kwiatkowski-Phillips-Schmidt-Shin (KPSS) and Augmented Dickey-Fuller (ADF) procedures as robustness check. We report the outcome of stationary tests for each variable at its level and first-differenced in Table. 2 where the first panel presents the results using the full sample. The second panel presents the results for a sub-sample of January 1975 to March 1999 which we will use later to compare our model to Saghaian, Marchant, Reed (2002) with similar study period.

According to PP test statistics, we fail to reject the null hypothesis of a unit root at 5% level for all variables in the full sample. The ADF test also confirms that all variables are nonstationary at their level. The The KPSS test shows similar conclusion except for exchange rates. The general conclusion is that variables are not stationary in levels. However, the absolute value of the PP and ADF test statistics increases after first-differencing, and therefore we can reject the null hypothesis for all series at 5% significance level. The KPSS test confirms this conclusion. In general the unit root test results imply that each series is an I(1) process. In this case, a VEC model is preferred to a VAR model.

<< Table. 2 >>

Since the period under the study is relatively long, we should account for possible structural breaks in the diagnostic tests and also the estimation procedure. Thus, we use a modified ADF test to examine the stationarity of each series in the presence of a structural break. For each univariate series of $\{y_t\}$, the modified ADF test compares the statistics of parameter α_1 in the regression model $\Delta y_t = \alpha_0 + \alpha_1 y_{t-1} + \sum_{j=1}^{n} \beta_j \Delta y_{t-j} + \alpha_2 b + \nu_t$, to the critical values proposed by Vogelsang (1993) where the null hypothesis is that the variable has a unit root. The refined specification of the ADF regression for each univariate series is obtained using a 'General to Specific' procedure in which *n* starts from a relatively large value. Then the common information criteria determine the optimum number of lags.

We checked for possible structural breaks in each series using Innovative Outlier (IO) and Additive Outlier (AO) approach. The results are reported in the last two rows of each panel in Table 3. The ADF test identified break dates that coincide with the economic downturn in 2002, the rapid increase in biofuel production capacity in 2006, and the financial crisis of 2008. Similar to Hansen (2003) we create three different dummy variables to control for these breaks and include them as exogenous variables in the Johansen cointegration test and the VEC estimation.

<< Table. 3 >>

Enders (2015) suggests that one can still model the long-run relationships and the short-run dynamics of a nonstationary variable when there is a possibility that a linear combination of them to be stationary. The necessary condition is that all nonstationary variables are integrated of the same order, i.e., cointegrated. To test whether our series are cointegrated, we follow the literature and use Johansen's (1991) cointegration method which uses a likelihood ratio (LR) test to determine the number of cointegrating vectors in the system. Theoretically, the number of cointegrating vectors (or the rank of the system) can be at most one less than the number of endogenous variables in the model. Therefore, the LR test determines whether there exist two cointegrating vectors between the five endogenous variables in our model. Table 4 presents the results of cointegration test for all series using the Trace statistics.

<< Table. 4 >>

Comparing the LR statistics at each rank to the critical values in Table 4 implies that we reject the null hypothesis that $r = 0$ and $r \leq 1$ at 5 % level. Therefore, the Johansen test identifies at most two cointegrating vectors in the system. The results from the Maximum Eigenvalue test (not reported) also confirms two cointegrating vectors. So, we expect two stationary linear combinations among the variables in our model.

Empirical Results

The Johansen's cointegrating test indicates that variables are cointegrated and therefore the VEC model is appropriate to analyze the long-run relationship among variables. The VEC model is a specific case of VAR where the first difference of each series is a function of its own lagged values, lagged values of other series and the cointegrating equations. We specified each cointegrating equation to have an intercept and a slope coefficient for money supply variable and use the residual of each equation in the VEC model. Similar to Saghaian, Reed, Marchant (2002), the VEC model is given by the following equations

$$\Delta p_{ct} = \sum_{j=1}^{k} \left(\alpha_{1j} \Delta p_{ct-j} + \beta_{1j} \Delta p_{et-j} + \gamma_{1j} \Delta p_{mt-j} + \delta_{1j} \Delta e_{t-j} + \phi_{1j} \Delta m_{t-j} \right) + \lambda_{11}(\tilde{\varepsilon}_{1t-1}) + \lambda_{12}(\tilde{\varepsilon}_{2t-1}) + \lambda_{13}(\tilde{\varepsilon}_{3t-1}) + \lambda_{14}(\tilde{\varepsilon}_{4t-1}) + \sum_{i=1}^{3} \eta_i b_i + \nu_{1t}$$

$$\Delta p_{et} = \sum_{j=1}^{k} \left(\alpha_{2j} \Delta p_{ct-j} + \beta_{2j} \Delta p_{et-j} + \gamma_{2j} \Delta p_{mt-j} + \delta_{2j} \Delta e_{t-j} + \phi_{2j} \Delta m_{t-j} \right) + \lambda_{21}(\tilde{\varepsilon}_{1t-1}) + \lambda_{22}(\tilde{\varepsilon}_{2t-1}) + \lambda_{23}(\tilde{\varepsilon}_{3t-1}) + \lambda_{24}(\tilde{\varepsilon}_{4t-1}) + \sum_{i=1}^{3} \eta_i b_i + \nu_{2t}$$

$$\Delta p_{mt} = \sum_{j=1}^{k} \left(\alpha_{3j} \Delta p_{ct-j} + \beta_{3j} \Delta p_{et-j} + \gamma_{3j} \Delta p_{mt-j} + \delta_{3j} \Delta e_{t-j} + \phi_{3j} \Delta m_{t-j} \right) + \lambda_{31}(\tilde{\varepsilon}_{1t-1}) + \lambda_{32}(\tilde{\varepsilon}_{2t-1}) + \lambda_{33}(\tilde{\varepsilon}_{3t-1}) + \lambda_{34}(\tilde{\varepsilon}_{4t-1}) + \sum_{i=1}^{3} \eta_i b_i + \nu_{3t}$$

$$\Delta e_{t} = \sum_{j=1}^{k} \left(\alpha_{4j} \Delta p_{ct-j} + \beta_{4j} \Delta p_{et-j} + \gamma_{4j} \Delta p_{mt-j} + \delta_{4j} \Delta e_{t-j} + \phi_{4j} \Delta m_{t-j} \right) + \lambda_{41}(\tilde{\varepsilon}_{1t-1}) + \lambda_{42}(\tilde{\varepsilon}_{2t-1}) + \lambda_{43}(\tilde{\varepsilon}_{3t-1}) + \lambda_{44}(\tilde{\varepsilon}_{4t-1}) + \sum_{i=1}^{3} \eta_i b_i + \nu_{4t}$$

$$\Delta m_t = \sum_{j=1}^{k} \left(\alpha_{5j}\Delta p_{ct-j} + \beta_{5j}\Delta p_{et-j} + \gamma_{5j}\Delta p_{mt-j} + \delta_{5j}\Delta e_{t-j} + \phi_{5j}\Delta m_{t-j}\right)$$
$$+ \lambda_{51}(\tilde{\varepsilon}_{1t-1}) + \lambda_{52}(\tilde{\varepsilon}_{2t-1}) + \lambda_{53}(\tilde{\varepsilon}_{3t-1}) + \lambda_{54}(\tilde{\varepsilon}_{4t-1}) + \sum_{i=1}^{3} \eta_i b_i$$
$$+ \nu_{5t}$$

in which Δ denotes the first difference of the natural logarithm of each variable, t represents months, and ηs are exogenous break dummy variables. in this model $\tilde{\varepsilon}_{1t-1} = p_{ct-1} - c_1 - \theta_1 m_{t-1}$, $\tilde{\varepsilon}_{2t-1} = p_{et-1} - c_2 - \theta_2 m_{t-1}$, $\tilde{\varepsilon}_{3t-1} = p_{mt-1} - c_3 - \theta_3 m_{t-1}$, and $\tilde{\varepsilon}_{4t-1} = e_{t-1} - c_4 - \theta_4 m_{t-1}$ are the 'disequilibrium residuals' from the cointegrating equations and α, β, γ, δ, ϕ, λ, η, c, and θ are unknown parameters to be estimated and v denotes the usual stochastic, errors. Since the expansionary monetary policy is expected to be inflationary, we expect θ_1, θ_2, and θ_3, to be positive but θ_4 to be negative. The latter implies that lower interest rates leads to the U.S. dollar depreciation relative to other currencies.

The λ parameter indicates the speed of adjustment in the system and shows how quickly each variable returns to its long-run equilibrium after a shock. For instance, the variable y_t would overshoot its long-run equilibrium when $c_i > 0$ and $\theta_i > 0$ in the cointegrating equation. In this case $\tilde{\varepsilon}_{it-1} > 0$ and $y_{t-1} > c_i + \theta_i m_{t-1}$ which implies that λ_{ii} should be negative and the variable has to fall in order to reestablish its long-run equilibrium in response to a monetary shock.

Based on our theoretical model, we expect λ_{11}, λ_{22}, and λ_{33} to be negative and $|\lambda_{11}| > |\lambda_{33}|$, since agricultural prices adjust faster than industrial prices. Since we assume flexible energy prices, $|\lambda_{22}| > |\lambda_{33}|$ is expected but we cannot conjecture on the relative speed of adjustment between agricultural prices and energy prices. Finally, if $\theta_4 < 0$ and $\pi_4 > 0$, we expect $\lambda_{44} < 0$ which implies that a U.S. dollar depreciation in response to a monetary shock would restore equilibrium.

We are estimating the normalized cointegrating equations and report the results in Table 5. We used an optimal lag length of 4 to estimate parameters c_i and θ_i. As the last row of the table shows, the empirical long-run relationships between $\{m_t\}$ and other variables have the expected sign (i.e., positive for prices and negative for the exchange rate). Note that the cointegrating equations are expressed as $\tilde{\varepsilon}_{1t-1} = p_{ct-1} - c_1 - \theta_1 m_{t-1}$.
<< Table. 5 >>

The response of prices to monetary shock is very similar in magnitude to energy and manufacturing prices. Agricultural prices respond the most to the increase in money supply. The slope coefficient is significant for the agricultural prices, manufacturing prices, and the exchange rate at 1% and energy prices at 5% level. If the money supply increase by 1 percent, agricultural, energy and manufacturing prices rise by 0.32, 0.23 and 0.27 percent, respectively, but the exchange rate increase only by 0.15 percent.

These empirical estimates, similar to previous findings, contradict the theoretical expectation on the neutrality of the money in the long-run because the change in prices are not unit proportional to the change in the money supply. If we incorporate these results (i.e., $\frac{d\bar{p}_c}{dm} < 1$, $\frac{d\bar{p}_m}{dm} < 1$, $\frac{d\bar{e}}{dm} < 1$ and $\frac{d\bar{p}_e}{dm} < 1$) into equation (30) from the theoretical model, the response of agricultural commodities to monetary shock can be specified as $\frac{dp_c}{dm} = \frac{d\bar{p}_c}{dm} + \frac{\alpha_1}{\alpha_2}\frac{d\bar{p}_m}{dm} + \left[\frac{\alpha_3}{\alpha_2}\frac{d\bar{p}_e}{dm} + \frac{\alpha_4+\lambda\zeta}{\alpha_2}\frac{d\bar{e}}{dm}\right] - \left[\frac{\alpha_3}{\alpha_2}\frac{dp_e}{dm} + \frac{\alpha_4+\lambda\zeta}{\alpha_2}\frac{de}{dm}\right]$ and agricultural prices will overshoot if $\frac{d\bar{p}_c}{dm} + \frac{\alpha_1}{\alpha_2}\frac{d\bar{p}_m}{dm} + \left[\frac{\alpha_3}{\alpha_2}\frac{d\bar{p}_e}{dm} + \frac{\alpha_4+\lambda\zeta}{\alpha_2}\frac{d\bar{e}}{dm}\right] > \left[\frac{\alpha_3}{\alpha_2}\frac{dp_e}{dm} + \frac{\alpha_4+\lambda\zeta}{\alpha_2}\frac{de}{dm}\right] + 1$, otherwise, they undershoot their long-run equilibrium.

We summarized the empirical estimation of the speeds of adjustment, λ, and other parameters of the VEC model in Table 6. The λ parameter for agricultural prices (λ_{11}), energy prices (λ_{22}), and the exchange rate (λ_{44}) is negative as expected and statistically significant. The negative sign implies that after a money supply shock, flexible prices and the exchange rate increase in the short run and must fall to reestablish the equilibrium. However, the adjustment coefficient for manufacturing prices (λ_{33}) is not statistically significant which may imply the stickiness of manufacturing prices in the short-run.

<< Table. 6 >>

The estimated coefficient of $\lambda_{11} = -0.060$ compared to $\lambda_{22} = -0.039$ and $\lambda_{44} = -0.012$ implies that agricultural prices are more flexible than energy prices and the exchange rates and adjust more quickly when they depart from the long-run money supply relationship. Other λ parameters can be interpreted as the response of each variable to the deviation of other variables from their long-run equilibrium. For instance, $\lambda_{12} = 0.033$ implies that agricultural prices must increase when energy prices undershoot their equilibrium. Similarly, $\lambda_{13} = -0.026$ and $\lambda_{14} = -0.052$ imply that agricultural prices must decrease if manufacturing prices and the exchange rate overshoot. The estimated parameters for the lagged-differenced variables are reported for completeness.

To examine the robustness of our model to the selection of monetary policy, we estimated the model with alternative measures for money supply. We also estimated the model using a sub-sample similar to the study period in Saghaian, Reed, and Marchant (2002), henceforward SRM, to compare our results with their findings. We summarize the estimation results for θ_is and λ_{ii}s of the four models, i.e., full sample with M1, full sample with M2, sub-sample (1975:1 to 1999:3), and SRM, in Table 7.

<< Table. 7 >>

In the second column of Table 7 we report the results of estimating our model using M2 to measure money supply. The estimated long-run coefficients in this model imply that a 1% increase in money supply leads to a 0.38 percent increase in agricultural prices, 0.57 percent increase in energy prices, and 0.39 percent increase in manufacturing prices. The response of exchange rates was not statistically significant. In the short-term, the estimated adjustment speeds for all variables are significant at 5% level and negative as expected, except for the manufacturing prices. Similar to our original model, the agricultural prices have the highest adjustment speed, followed by energy prices and exchange rates. Comparing the two full sample models show that the use of alternative measures for the money supply impacts the long-run response. When M2 is used as the measure of money supply, energy prices response is largest followed by manufacturing and agricultural prices.

The long-run rate of increase in agricultural prices, θ_{pc}, in our models is statistically significant ($p < 0.05$) but less than the SRM model in magnitude. The estimates for θ_{pc} show that in response to 1% increase in money supply, agricultural prices increase 0.13 to 0.43 percent in the long-run, depending on the model used.

Similarly, the estimated long-run relationship between money supply and the manufacturing prices is significant ($p < 0.01$) in all models but larger in the SRM model. Having in mind that different data, period, and estimation procedure could be the underlying cause of the difference in estimations, one reason that our estimations of θ_{cp} and θ_{pm} are smaller than the SRM model could be due to the energy prices in our model. In other words, energy prices moderate the response on agricultural and manufacturing prices to the money supply shock.

There is evidence of a long-run equilibrium between energy prices and money supply since θ_{pe} is negative and significant in our models. Although, this coefficient is weakly significant ($p < 0.1$) in the sub-sample. The coefficient for the exchange rates is statistically significant ($p < 0.01$) in the model with M1 money supply and the sub-sample model while it is not significant in the model with M2 money supply and the SRM model. Comparing the magnitudes, the response of the exchange rate to money supply increase is largest in our model for the 1975 to 1999 sub-sample. All estimated θ_is are less than unity which means that none of the four models finds empirical evidence of money neutrality in the long run.

The estimated speeds of adjustment in the sub-sample are all negative as expected. However, the parameters for agricultural prices and energy prices are significant at 10% and for manufacturing prices at 1% level. Hence, $\lambda_{11} = -0.061$, $\lambda_{22} = -0.009$, and $\lambda_{33} = -0.018$ imply that prices should fall to restore equilibrium after they overshoot. The relationship $|\lambda_{11}| > |\lambda_{33}|$ is consistent with our theoretical assumption that agricultural prices adjust faster than manufacturing prices. However, the speed of adjustment for energy prices is far less than expected. Similar to the SRM model, the λ parameter is not significant in 1975 to 1999 period.

We assumed in the theoretical model that a dynamic system with perfect foresight have a saddle point solution because the system has both positive and negative characteristic roots. The stability condition requires that all characteristic roots remain within the unit circle. To test this condition, we mapped the autoregressive characteristic roots of the polynomial in the estimated VEC model. Figure 1 shows that all the characteristics roots for our model remain inside the unit circle.

<< Figure. 1 >>

To track the dynamic response of endogenous variables in this model (i.e., agricultural prices, energy prices, manufacturing prices, and exchange rates) to one standard deviation change of money supply, we depict the Impulse Response Functions (IRFs) over 72 months in Figure 2, using a full sample. IRFs show that upon a positive money supply shock, agricultural prices were the most volatile in early months, followed by energy prices and exchange rates. Agricultural prices respond positively at the initial month, and then fall and rise again. After five months, agricultural prices start to increase sharply and then reach to a stable level at the end of the second year. Energy prices rise immediately after the shock for three months, then fall. They rise continuously for 10 months before smoothing out at the end of the second year. Exchange rates fall slightly at the first month, then rise above their previous level but fall again sharply up until the sixth month after the shock. Manufacturing prices, however, were the least volatile and increased steadily but slowly right after the shock for more than a year before leveling off. We presented the IRFs using a sub-sample for January 1975 to March 1993 period in Figure 3. The general pattern of responses are similar to the full sample. Although agricultural prices were more instable in the sub-sample and even fall below their initial levels in the first few months before they sharply increase and reach a stable level.

Summary of Empirical Results

We followed the time series econometric literature to specify our empirical macroeconometric system. We find that our nonstationary series are cointegrated of order one, I(1), and therefore use the VEC model to estimate the long run relationships and determine the short run adjustment parameters for agricultural commodities prices, energy prices, manufacturing prices, and the exchange rate in response to a money supply shock. We include exogenous dummy variables in tests and model estimation to control for possible structural breaks in the period of the study. We identify three major breaks that coincide with economic downturn in 2002, rapid growth in biofuel production in 2006, and the financial crisis of 2008. We also estimate our model using a sub-sample for the period of 1975:1 to 1999:3 to be able to compare our results to findings of SRM (2002).

We did not find empirical evidence for money neutrality in the long-run which contrast our theoretical expectation. This result, however, is consistent with empirical findings of SRM (2002). When using the full sample, the long-run response of agricultural prices to 1% increase in money supply is the largest followed by the manufacturing and energy prices. The exchange rate has the lowest rate of increase. However, when alternative measures of money supply was used in our model, the long-run response was largest for energy prices followed by manufacturing and agricultural prices. In contrast, SRM (2002) finds the larger rate of increase in manufacturing prices. The coefficient for the exchange rate was not significant in their study. In general, long-run increase rates are lower in our model. Although the change in magnitude of responses in different models imply that the results should be interpreted with caution, one possible explanation for the difference in estimations could be the energy prices in our model.

Our estimation of speeds of adjustment shows that in response to a money supply innovation, agricultural prices adjust faster than other prices and the exchange rate. However, the speed of adjustment for agricultural prices in our model is slower than the SRM (almost half) which could indicate that energy prices share the burden of the shock with other flexible prices. The difference in estimations across the three model implies that different data and period may affect the empirical estimations and therefore these results should be interpreted with caution.

In general, we find some evidence that energy prices absorb, to some extent, the impact of a monetary shock and therefore modify the overshooting of agricultural prices and the exchange rate. Comparing the estimates of the full sample with the sub-sample shows that the long-run response rate of agricultural prices has increased over the time while it has decreased for other price and the exchange rate.

In light of recent changes to the monetary policy, increasing the interest rates is expected to plummet agricultural prices. The theoretical and empirical results in this study imply that the extent of decrease (i.e., overshooting) in the agricultural prices would be less than what previous models would have predicted. Therefore the income instability caused by the monetary policy in the short run and the long run is expected to be less concerning. However, careful monetary policy can always smooth out fluctuations in the relative prices and warrant more stable farm income although it would not eliminate income risk. Farmers can further reduce income risk through using risk management tools like insurance, diversification, and options markets.

The analysis of the impulse response functions show that after a money supply shock, agricultural prices were the most responsive, followed by energy prices and exchange rates. In both full sample and the sub-sample, the volatility of prices and exchange rates happen during the first 5 to 10 months. The sluggish adjustment of manufacturing prices were evident from the corresponding impulse response functions.

Tables

Table 1. Descriptive Statistics of Variables

Variable	Mean	Standard Deviation	Minimum	Maximum
Money supply, M1 [z]	1216.586	809.127	269.900	3636.400
Exchange rate [y]	95.733	9.395	80.295	128.437
Agricultural prices, PPI [x]	119.667	32.461	70.600	211.000
Industrial prices, PPI	132.091	42.494	53.600	209.500
Energy prices, PPI	111.532	52.872	33.500	268.700

Note: monthly observations from 1975:01 to 2017:12.

[z] money stock in billions of dollars, not seasonally adjusted.

[y] Real Broad Dollar Index (March. 1973 = 100), is a weighted average of the foreign exchange values of the U.S. dollar against the currencies of a large group of major U.S. trading partners.

[x] All producer prices are an index (1982 = 100), not seasonally adjusted.

Table 2. Unit Root Test Results

Statistics	p_{ct}	p_{et}	p_{mt}	e_t	m_t
Full Sample					
Variables in Levels					
Phillips-Perron [z]	1.633	2.023	2.777^{*}	1.959	0.003
KPSS [y]	2.208^{***}	2.292^{***}	2.713^{***}	0.279	2.776^{***}
ADF [z]	1.672	2.057	2.684^{*}	2.180	0.435
First-Differenced Variables					
Phillips-Perron	20.195^{***}	16.290^{***}	14.751^{***}	15.617^{***}	26.240^{***}
KPSS	0.048	0.119	0.443^{*}	0.069	0.262
ADF	12.935^{***}	16.307^{***}	14.682^{***}	15.662^{***}	2.965^{**}
Sub-sample (1975:1-1999:3)					
Variables in Levels					
Phillips-Perron	2.663^{*}	2.717^{*}	1.351	1.348	2.149
KPSS	1.203^{***}	0.716^{**}	$0.387^{***\ x}$	0.321	2.006^{***}
ADF	2.974^{**}	2.754^{*}	1.438	1.584	1.760
First-Differenced Variables					
Phillips-Perron	14.511^{***}	9.597^{***}	9.485^{***}	11.717^{***}	18.936^{***}
KPSS	0.198	0.552^{**}	$0.131^{*\ x}$	0.166	0.647^{**}
ADF	14.633^{***}	10.020^{***}	9.605^{***}	11.921^{***}	2.159

Note: *** significant at 1% level, ** significant at 5% level, * significant at 10% level.

[z] In absolute value and compared to MacKinnon (1996) critical values (3.443 at 1%, 2.867 at 5%, and 2.570 at 10% level). The null hypothesis for both tests is that series are non-stationary.

[y] In absolute value and compared to Kwiatkowski-Phillips-Schmidt-Shin (1992) asymptotic critical values (0.739 at 1%, 0.463 at 5%, and 0.347 at 10% level). The null hypothesis for this test is that series are stationary.

[x] Compared to KPSS critical values with trend (0.216 at 1%, 0.146 at 5%, and 0.119 at 10% level).

Table 3. ADF Test Results with Structural Break

Statistics	P_{ct}	P_{et}	P_{mt}	e_t	m_t
Variables in Levels					
ADF test ^{z}	4.25^{*}	3.92	3.91	2.70	3.12
F test	7950.59^{***}	24494.71^{***}	198289.50^{***}	8438.65^{***}	136823.30^{***}
AIC	-4.51	-3.92	-6.64	-6.07	-6.41
Schwarz criterion	-4.45	-3.87	-6.60	-6.03	-6.27
Durbin Watson	2.01	1.98	2.03	1.93	1.99
Lag length	3	1	1	1	13
Break date (IO ^{y})	2006:05	2002:02	2002:02	1985:05	2008:08
Break date (AO ^{x})	2005:12	2002:01	2002:01	1985:01	2006:10
First-Differenced Variables					
ADF test	20.26^{***}	16.96^{***}	15.69^{***}	16.17^{***}	25.95^{***}
F test	3.32^{**}	24.54^{***}	42.92^{***}	30.69^{***}	4.48^{***}
AIC	-4.45	-3.92	-6.66	-6.08	-5.48
Schwarz criterion	-4.42	-3.89	-6.63	-6.05	-5.45
Durbin Watson	2.03	2.02	2.08	1.92	2.09
Lag length	0	0	0	0	0
Break date (IO)	1975:11	2008:11	2008:11	2008:10	1976:02
Break date (AO)	2005:12	2008:11	2008:11	2008:10	1976:02

Note: *** significant at 1% level, ** significant at 5% level, * significant at 10% level.

[z] In absolute value and compared to Vogelsang (1993) asymptotic critical values (4.949 at 1%, 4.444 at 5%, and 4.194 at 10% level).

[y] Innovative Outlier approach.

[x] Additive Outlier approach.

Table 4. Johansen Cointegration test Results

Null Hypothesis [z]	Trace Statistics	5% Critical Value	Eigenvalue
$r = 0^{**}$	158.409	76.973	0.184
$r \leq 1^{**}$	54.844	54.079	0.050
$r \leq 2$	28.917	35.193	0.031
$r \leq 3$	12.687	20.262	0.017
$r \leq 4$	3.757	9.165	0.007

[z] r is the cointegration rank.

[**] reject the null hypothesis at the 0.05 level compared to MacKinnon, Haug, and Michelis (1999) p-values.

Table 5. Parameter Estimates for Normalized Cointegrating Vectors

Variable	$\tilde{\varepsilon}_{1t-1}$	$\tilde{\varepsilon}_{2t-1}$	$\tilde{\varepsilon}_{3t-1}$	$\tilde{\varepsilon}_{4t-1}$
p_{ct-1}	1.000	0.000	0.000	0.000
p_{et-1}	0.000	1.000	0.000	0.000
p_{mt-1}	0.000	0.000	1.000	0.000
e_{t-1}	0.000	0.000	0.000	1.000
Intercept	-2.289***	-2.692***	-2.968***	-5.612***
	(0.302)	(0.900)	(0.465)	(0.365)
m_{t-1}	-0.319***	-0.227**	-0.267***	0.146***
	(0.043)	(0.127)	(0.065)	(0.051)

Note: *** significant at 1% level, ** significant at 5% level, * significant at 10% level. Standard errors in parenthesis.

Table 6. Vector Error Correction Model Parameter Estimates and Diagnostics

Variable	Δp_{ct}	Δp_{et}	Δp_{mt}	Δe_t	Δm_t
$\tilde{\varepsilon}_{1t-1}$	-0.060^{***}	0.044^{**}	0.008	-0.006	0.007
$\tilde{\varepsilon}_{2t-1}$	0.033^{***}	-0.039^{**}	-0.006	0.013^{**}	0.023^{***}
$\tilde{\varepsilon}_{3t-1}$	-0.026^{**}	0.044^{**}	0.006	-0.019^{***}	-0.040^{***}
$\tilde{\varepsilon}_{4t-1}$	-0.052^{***}	0.048^{**}	0.008	-0.012^{*}	-0.012
$\Delta p_{ct\text{-}1}$	0.104^{**}	0.100	0.035^{**}	0.021	0.011
$\Delta p_{ct\text{-}2}$	0.134^{***}	0.035	0.001	-0.004	-0.012
$\Delta p_{ct\text{-}3}$	-0.120^{***}	-0.064	-0.019	0.003	0.008
$\Delta p_{ct\text{-}4}$	-0.056	-0.012	-0.002	-0.011	-0.009
$\Delta p_{et\text{-}1}$	-0.193^{**}	0.383^{***}	0.031	-0.101^{**}	0.164^{***}
$\Delta p_{et\text{-}2}$	-0.091	-0.305^{**}	-0.087^{***}	0.093^{**}	-0.241^{***}
$\Delta p_{et\text{-}3}$	0.026	-0.025	-0.054	0.022	0.068
$\Delta p_{et\text{-}4}$	-0.038	-0.033	0.010	-0.015	0.133^{**}
$\Delta p_{mt\text{-}1}$	0.425	-0.544	0.141	0.497^{***}	-0.905^{***}
$\Delta p_{mt\text{-}2}$	0.742^{*}	1.264^{**}	0.411^{***}	-0.441^{**}	0.871^{***}
$\Delta p_{mt\text{-}3}$	-0.401	0.472	0.293^{**}	-0.209	-0.277
$\Delta p_{mt\text{-}4}$	0.093	0.330	0.028	-0.005	-0.768^{***}
$\Delta e_{t\text{-}1}$	-0.080	-0.229^{*}	-0.076^{**}	0.394^{***}	-0.151^{***}
$\Delta e_{t\text{-}2}$	0.214^{**}	0.088	0.025	-0.101^{**}	-0.099^{*}
$\Delta e_{t\text{-}3}$	-0.146	0.021	0.0002	0.004	0.014
$\Delta e_{t\text{-}4}$	-0.149	0.195	0.050	-0.038	-0.068
$\Delta m_{t\text{-}1}$	0.112	0.099	0.042	-0.016	-0.210^{***}
$\Delta m_{t\text{-}2}$	-0.121	0.054	0.018	0.007	-0.363^{***}
$\Delta m_{t\text{-}3}$	0.082	-0.038	0.029	-0.026	0.028
$\Delta m_{t\text{-}4}$	-0.157^{*}	-0.009	0.031	-0.103^{***}	-0.006
Break (2006)	0.002	0.015^{**}	0.004^{***}	-0.006^{***}	-0.006^{**}
Break (2008)	-0.049^{***}	-0.092^{***}	-0.029^{***}	0.019^{***}	0.027^{***}
R^2	0.192	0.208	0.308	0.203	0.301
Akaike IC	-4.562	-3.929	-6.713	-6.055	-5.730
Schwarz IC	-4.355	-3.721	-6.506	-5.848	-5.523
Jarque-Bera	7.785^{**}	299.521^{***}	454.880^{***}	15.700^{***}	13.729^{***}

Note: *** significant at 1% level, ** significant at 5% level, * significant at 10% level.

Table 7. Long-run Cointegrating Vectors and Short-run Adjustment parameters

parameters	Model I [z]	Model II [y]	Model III [x]	SRM [w] (2002)
θ_{pc}	-0.316***	-0.381***	-0.131**	-0.430***
	(0.041)	(0.059)	(0.056)	(0.132)
θ_{pe}	-0.234**	-0.574***	-0.300*	N/A
	(0.126)	(0.089)	(0.180)	
θ_{pm}	-0.270***	-0.389***	-0.341***	-0.773***
	(0.065)	(0.040)	(0.089)	(0.140)
θ_{e}	0.142***	0.068	0.355***	0.068
	(0.050)	(0.046)	(0.072)	(0.135)
λ_{11}	-0.060***	-0.039***	-0.061*	-0.135***
λ_{22}	-0.039**	-0.021**	-0.009*	N/A
λ_{33}	0.006	0.001	-0.018***	-0.007**
λ_{44}	-0.012*	-0.020***	-0.007	-0.009

Note: *** significant at 1% level, ** significant at 5% level, * significant at 10% level. Standard errors in parenthesis.

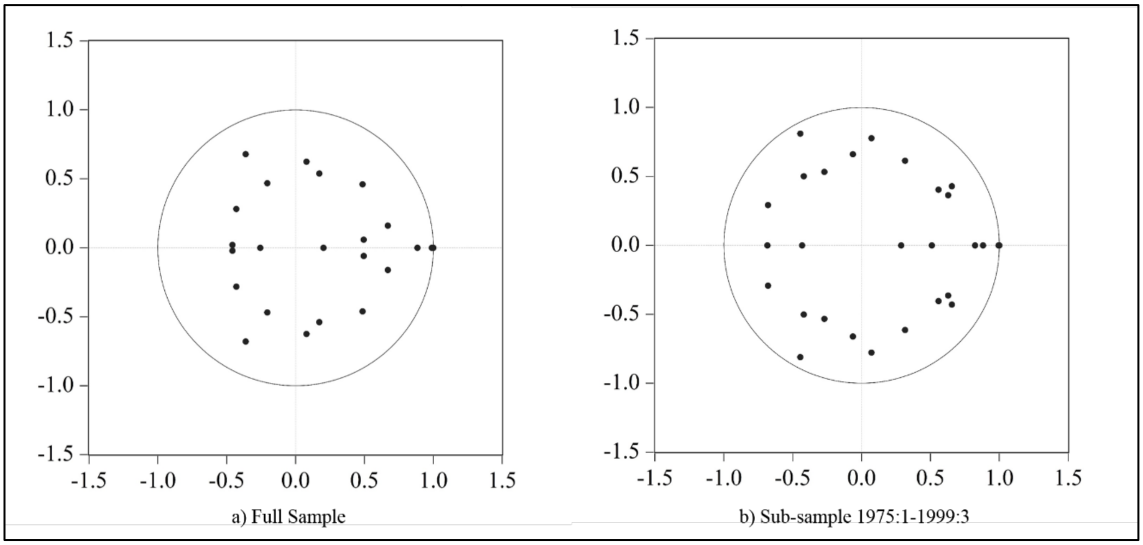
[z] Full sample is used and money supply was measured by M1 in this model.

[y] Full sample is used and money supply was measured by M2 in this model.

[x] Sub-sample (1975:1-1999:3) is used.

[w] Saghaian, Reed, and Marchant (2002).

Figures



a) Full Sample

b) Sub-sample 1975:1-1999:3

Figure 1. Stability of the VEC Model

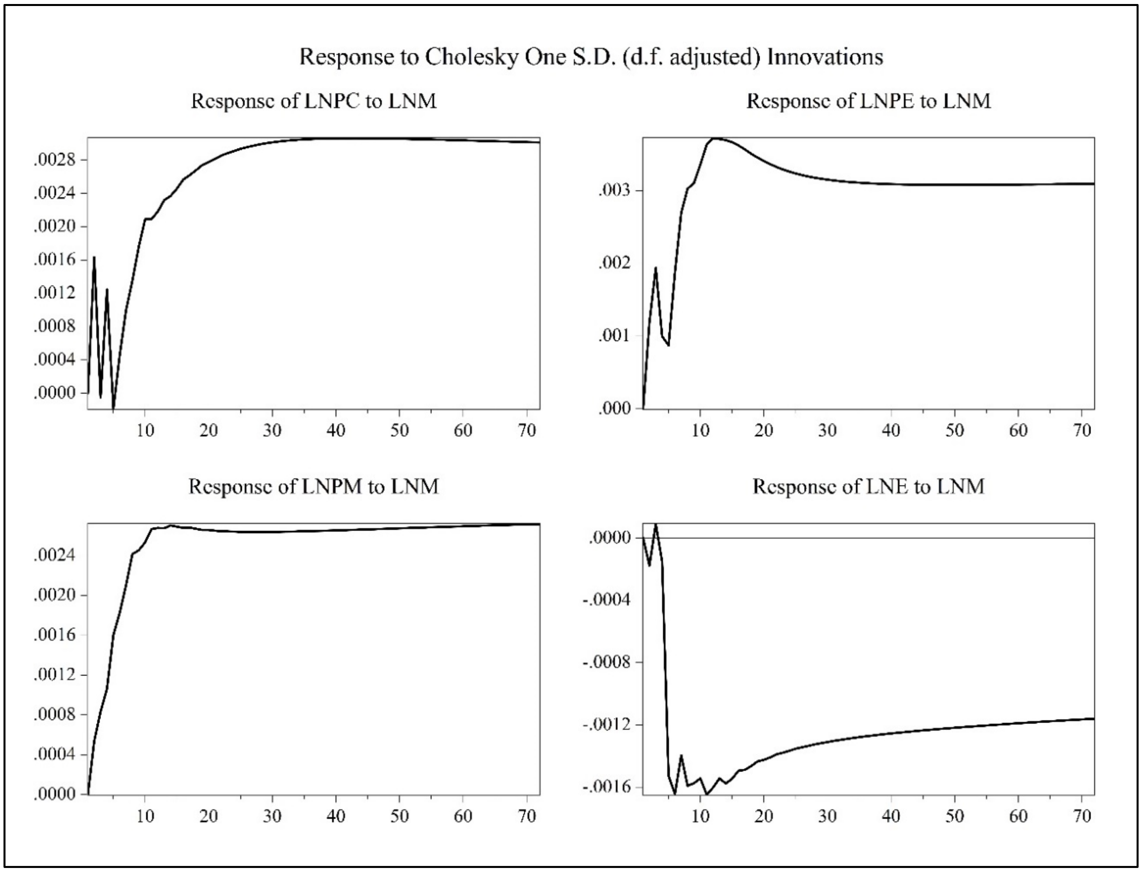


Figure 2. Impulse Response Functions to Monetary Shocks (Full Sample)

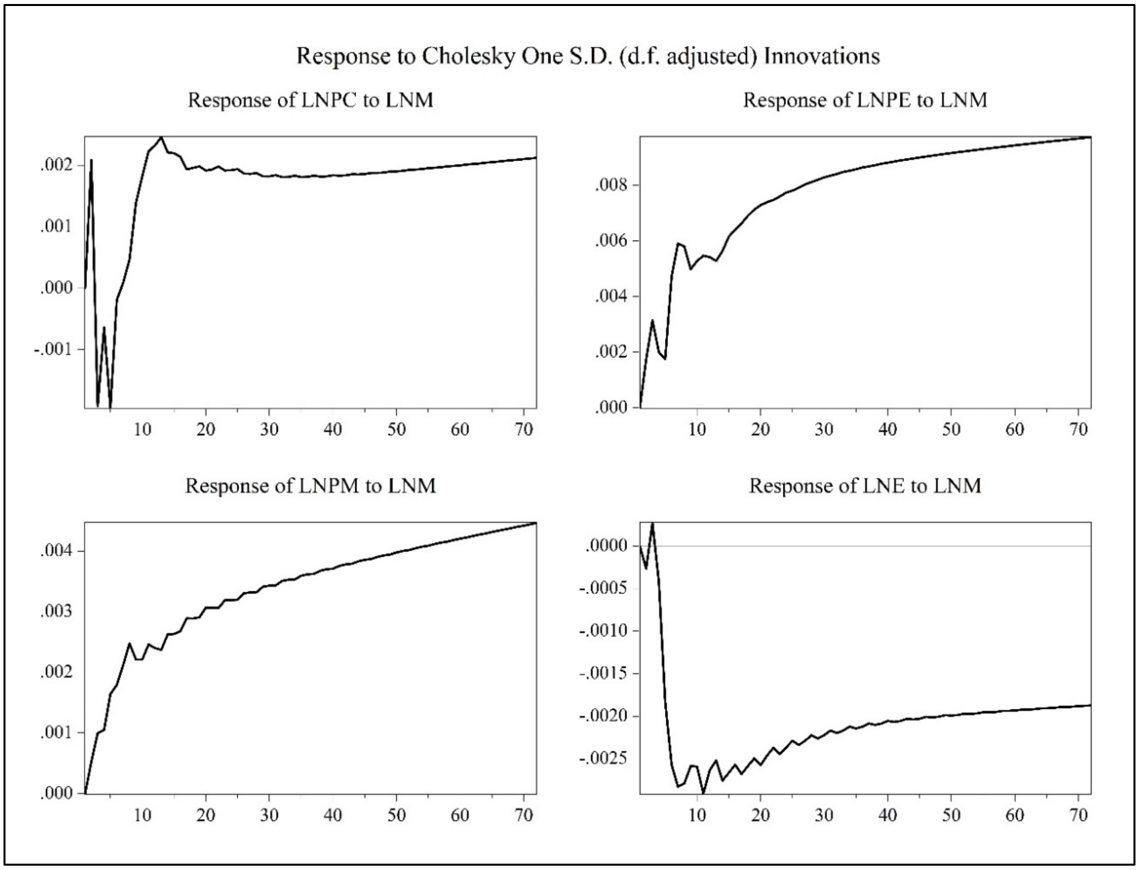


Figure 3. Impulse Response Functions to Monetary Shocks (1975:1 to 1999:3)

Chapter 5. Discussion, Policy implications, and Conclusions

From the structural point of view, real supply and demand factors determine agricultural prices in the commodity markets. Commodity price volatility, specifically in the context of recent high prices, significantly impacts the farm income stability and financial viability. Analyzing the sources of the price instability enables a more informed policy response. Whether the source of instability is inherent in the agricultural production system or arises from the public policy would shape the response (Taylor and Spriggs 1989). Monetary policy, as reflected in real interest rates, impacts real commodity prices through different channels. Money restriction leads to higher interest rates which in turn a) encourages earlier extraction, b) discourages inventories, and c) encourages shifting out of commodity contracts. All three channels ultimately reduce the prices (Frankel 2008). It is important to note that macroeconomic policies can only dominate the short-run impact of agricultural policies on the price and income path for the U.S. agriculture but, in the long run, agricultural sector policies have a more significant influence on resource allocation (Rausser, Chalfant, Stamoulis 1985).

In his seminal paper, Dornbusch (1976) showed that due to the differential adjustment speed of asset markets and goods markets, in the short run, the exchange rates overshoot in response to monetary shocks. He, therefore argues that the flexible exchange rates are stabilizing forces in the economy. Saghaian, Reed, and Marchant (2002) generalized the overshooting hypothesis to include agricultural prices, manufacturing prices, and exchange rates in an open economy. Their empirical results show that exchange rates and agricultural prices are flexible and adjust faster than industrial prices to money supply innovations in the short run. These results are important from the policy perspective because if the short run impact of monetary surprises is persistent, then the short-run response is informative about the longer-run response (Scrimgeour 2014).

We modify the model proposed by Saghaian, Reed, and Marchant (2002) by including the energy sector as the fourth independent market to the model which has a unique adjustment path in response to shocks. Energy conservation and environmental policy in recent decades have created a link between the energy sector and agricultural sector through mandating biofuel production. To address this link, we include the energy demand for agricultural commodities to the market clearing condition for the agricultural market. Biofuel production absorbs a significant amount of feedstock crops which increases the interdependence between agricultural commodity markets and energy markets. Therefore, commodity prices are more resistant to different shocks occurring in agricultural markets. The response of commodity prices to exogenous market shocks is smaller in the presence of biofuels indicating that in some cases, biofuels reduce the magnitude of price adjustment in commodity markets (Drabik, Ciaian, and Pokrivčák 2016). Further, we assume that fuel markets represent the energy sector and that total fuel consumption is a weighted average of fossil fuel and biofuel consumption. We re-evaluate our theoretical results when the share of the biofuel consumption is explicitly specified in the model.

According to Dornbusch (1976), the share of the fix-price sector in the general price level determines the extent of the overshooting in other sectors with flexible prices. Our theoretical results show that including the energy sector in the model reduces the role of manufacturing prices and further moderates the overshooting of the agricultural prices. In fact, we show that energy prices share the burden of monetary shocks with the exchange rates and agricultural prices. In our model, this moderation effect decrease when the share of biofuel from total fuel consumption increase. Thus higher biofuel mandates could contribute to the overshooting of agricultural prices.

The extent of overshooting or undershooting is, of course, an empirical question. Substantial number of empirical work has tested the overshooting hypothesis in different settings, including using data from different countries (Taylor and Spriggs 1989; Saghaian, Hasan, Reed 2002; Frankel 2008), using aggregated price index versus individual commodity prices (Saghaian, Reed, Hasan 2006; Bamba, Reed, Saghaian 2008; Bakucs and Fertő 2013;Scrimgeour 2014), and using alternative autoregressive specifications (Awokuse 2005). However, the role of the energy sector in the economy has been mostly ignored in this literature except for Hu *et al*. (2015) that shows the increasing share of biofuel in total energy consumption has a positive impact on agricultural prices in the short-run but opposite in the long run.

The complex nature of the functions specified in the theoretical section does not allow us to directly identify all parameters and quantify the price response. Therefore, we employed the time-series modeling approach for nonstationary variables to estimate the short-run and long-run relationships between the price of agricultural commodities, energy, manufacturing, exchange rate, and the money supply. We used monthly data (from January 1975 to December 2017) and vector autoregressive approach in our empirical analysis. We estimate our macroeconometric model using the full sample and a sub-sample of January 1975 to March 1999. The sub-sample coincide with the study period in SRM (2002). We compare our empirical results with their findings.

In contrast to our theoretical assumption, we did not find any empirical evidence of money neutrality in the long-run. Compared to SRM (2002) we find the smaller long-run rate of increase in prices and the exchange rate which could partly explain by the presence of energy prices in our model. Agricultural prices still overshoot but in our model nut not as much as the previous model. One interpretation is that energy prices share the impact of monetary shock with other flexible prices. However, long-run estimations and short-run parameters could change when different data and period are applied in the model. Thus further research could identify and eliminate the possible biases in these estimations.

Our empirical results are consistent with our theoretical expectation and the findings of previous studies that agricultural prices adjust faster than industrial prices to monetary shocks. We show that including the energy prices in the model, reduces the extent of overshooting of the agricultural prices. Therefore we expect the disturbances to the farm income variability, in response to monetary policy, to be less than what prior model would have estimated. Increased share of biofuels, however, increase the extent of overshooting of agricultural prices and therefore have an adverse effect on the farm price stability. In general, we find energy prices as a stabilizing factor in our model, but we suspect that this role would be less effective if higher biofuel mandates are enforced.

The current level of real interest rates and the gradual increase in the nominal rates indicate that the policymakers favor contractionary monetary policy at this time. In this case, the rate of monetary expansion may be reduced which should have a negative effect on the commodity prices. Agricultural prices may drop instantly in response to the new monetary policy, and return to their long-run equilibrium gradually. Our theoretical model predicts a smaller overshooting, compared to previous models, due to a higher share of flexible sectors in our specification. Comparing our empirical estimates with that of SRM shows that agricultural prices overshoot less and adjust slower in our model. Therefore farm income is expected to fall less than the previous models would have predicted but to take longer to return to its long-run level.

Appendix A

When we add the energy sector to the economy, the system of equations (9), (22), (23) and (24) can be expressed as follows:

$$\begin{bmatrix} \dot{e} \\ \dot{p}_c \\ \dot{p}_m \\ \dot{p}_e \end{bmatrix} = \begin{bmatrix} \Psi_1 & \Psi_2 & \Psi_3 & \Psi_4 \\ \Sigma_1 & \Sigma_2 & \Sigma_3 & \Sigma_4 \\ \Pi_1 & \Pi_2 & \Pi_3 & \Pi_4 \\ \Omega_1 & \Omega_2 & \Omega_3 & \Omega_4 \end{bmatrix} \times \begin{bmatrix} (e - \bar{e}) \\ (p_c - \bar{p}_c) \\ (p_m - \bar{p}_m) \\ (p_e - \bar{p}_e) \end{bmatrix} + \begin{bmatrix} 0 \\ -\dfrac{\alpha_1}{\alpha_2} \\ 1 \\ 0 \end{bmatrix} \mu \qquad \text{(A-1)}$$

where:

$$\Psi_1 = \frac{\alpha_4}{\lambda} > 0 \qquad \Psi_2 = \frac{\alpha_2}{\lambda} > 0 \qquad \Psi_3 = \frac{\alpha_1}{\lambda} > 0 \qquad \Psi_4 = \frac{\alpha_3}{\lambda} > 0$$

$$\Sigma_1 = \frac{-1}{\alpha_2}\left(\pi\alpha_1\delta_1 + \frac{(1 - \rho\Phi\alpha_3 - \sigma\pi\alpha_1)}{\theta}\gamma_1 - \frac{\alpha_4(1-\alpha_4)(1-\sigma\pi\alpha_1)}{\lambda}\right)$$

$$\Sigma_2 = \frac{-1}{\alpha_2}\left(\Phi\alpha_3\beta_2 + \pi\alpha_1\delta_2 - \frac{(1 - \rho\Phi\alpha_3 - \sigma\pi\alpha_1)}{\theta}(\gamma_1 + \gamma_2) - \frac{\alpha_2(1-\alpha_4)}{\lambda}\right)$$

$$\Sigma_3 = \frac{-1}{\alpha_2}\left(\Phi\alpha_3\beta_1 - \pi\alpha_1(\delta_1 + \delta_1) + \frac{(1 - \rho\Phi\alpha_3 - \sigma\pi\alpha_1)}{\theta}\gamma_2 - \frac{\alpha_1(1-\alpha_4)}{\lambda}\right)$$

$$\Sigma_4 = \frac{1}{\alpha_2}\left(\Phi\alpha_3(\beta_1 + \beta_2) + \frac{\alpha_3(1-\alpha_4)}{\lambda}\right) > 0$$

$$\Pi_1 = \pi\left(\delta_1 - \frac{\sigma}{\theta}\gamma_1\right) \qquad \Pi_2 = \pi\left(\delta_2 + \frac{\sigma}{\theta}(\gamma_1 + \gamma_2)\right) > 0$$

$$\Pi_3 = -\pi\left(\delta_1 + \delta_2 + \frac{\sigma}{\theta}\gamma_2\right) < 0 \qquad \Pi_4 = 0$$

$$\Omega_1 = -\Phi\frac{\rho}{\theta}\gamma_1 < 0 \quad \text{if } \rho^d > \rho^s \qquad \Omega_2 = \Phi\left(\beta_2 + \frac{\rho}{\theta}(\gamma_1 + \gamma_2)\right) > 0 \quad \text{if } \rho^d > \rho^s$$

$$\Omega_3 = \Phi\left(\beta_1 - \frac{\rho}{\theta}\gamma_2\right) > 0 \quad \text{if } \rho^d < \rho^s \qquad \Omega_4 = -\Phi(\beta_1 + \beta_2) < 0$$

Appendix B

When there is a biofuel policy, the system of equations for $\dot{e}$, $\dot{p}_c$, $\dot{p}_m$, and $\dot{p}_f$ can be expressed as follows:

$$\begin{bmatrix} \dot{e} \\ \dot{p}_c \\ \dot{p}_m \\ \dot{p}_f \end{bmatrix} = \begin{bmatrix} \Psi_1 & \Psi_2 & \Psi_3 & \Psi_4 \\ \Sigma_1 & \Sigma_2 & \Sigma_3 & \Sigma_4 \\ \Pi_1 & \Pi_2 & \Pi_3 & \Pi_4 \\ \Omega_1 & \Omega_2 & \Omega_3 & \Omega_4 \end{bmatrix} \times \begin{bmatrix} (e - \bar{e}) \\ (p_c - \bar{p}_c) \\ (p_m - \bar{p}_m) \\ \left(p_f - \bar{p}_f\right) \end{bmatrix} + \begin{bmatrix} 0 \\ -\dfrac{\alpha_1}{\alpha_2} \\ 1 \\ 0 \end{bmatrix} \mu \tag{B-1}$$

where Ψ_i, Σ_i, and Π_i are the same as equation (A-1) but:

$$\Omega_1 = \frac{\Phi}{\kappa}\left(\beta_1 - \frac{\rho}{\theta}\gamma_1\right) \qquad \Omega_2 = -\frac{\Phi}{\kappa}\left(\beta_3 - \frac{\rho}{\theta}(\gamma_1 + \gamma_2)\right)$$

$$\Omega_3 = -\frac{\Phi}{\kappa}\left(\frac{\rho}{\theta}\gamma_2\right) < 0 \qquad \Omega_4 = -\frac{\Phi}{\kappa}\left(\kappa\beta_1 + (1-\omega)\beta_2 - \omega\beta_3 + \frac{\rho\omega}{\theta}\gamma_3\right)$$

References

Anzuini, A., M.J. Lombardi, and P. Paganoa. 2013. “The Impact of Monetary Policy Shocks on Commodity Prices.” *International Journal of Central Banking* 9(3):119-144.

Awokuse, T.O. 2005. “Impacts of Macroeconomic Policies on Agricultural Prices.” *Agricultural and Resource Economics Review* 34(2):226-237.

Ayres, R.U., J.C.J.M. Van den Bergh, D. Lindenberger, and B. Warr. 2013. “The Underestimated Contribution of Energy to Economic Growth.” *Structural Change and Economic Dynamics* 27:79-88.

Babcock, B.A. 2013. “Ethanol without Subsidies: An Oxymoron or the New Reality?” *American Journal of Agricultural Economics* 95(5): 1317-1324.

Baffes, J. 2013. “A Framework for Analyzing the Interplay among Food, Fuels, and Biofuels.” *Global Food Security* 2(2):110-116.

Baffes, J., and T. Haniotis. 2010. “Placing the 2006/08 Commodity Price Boom into Perspective.” Working paper 5371, The World Bank.

Bakucs, Z., and I. Fertő. 2013. “Monetary Impacts and Overshooting of Agricultural Prices in a Transition Economy: The Case of Hungary.” *African Journal of Agricultural Research* 8(23):2911-2917.

Bamba, I., M. Reed, and S. Saghaian. 2008. “Monetary Policy Impacts on Coffee and Cocoa Prices.” *Journal of International Agricultural Trade and Development* 4(2):273-291.

Barnett, R.C., D.A. Bessler, and R.L. Thompson. 1983. “The Money Supply and Nominal Agricultural Prices.” *American Journal of Agricultural Economics* 65(2):303-307.

Basistha, A., and A. Kurov. 2015. “The Impact of Monetary Policy Surprises on Energy Prices.” *The Journal of Futures Markets* 35(1):87-103.

Berndt, E.R., and D.O. Wood. 1975. “Technology, Prices, and the Derived Demand for Energy.” *The Review of Economics and Statistics* 57(3):259-268.

Bessler, D.A., and S. Lee. 2002. “Money and Prices: US Data 1869–1914 (A Study with Directed Graphs).” *Empirical Economics* 27(3):427-446.

Bordo, M.D. 1980. “The Effects of Monetary Change on Relative Commodity Prices and the Role of Long-Term Contracts.” *Journal of Political Economy* 88(6):1088-1109.

Borensztein, E., and C.M. Reinhart. 1994. “The Macroeconomic Determinants of Commodity Prices.” Staff Papers, International Monetary Fund 41(2): 236-261.

Cairnes, J.E. 1965. *Essays on Political Economy: Theoretical and Applied*. 1873. Reprint. New York: Kelley.

Chen, X. and M. Khanna. 2012. “Food vs. Fuel: The Effect of Biofuel Policies.” *American Journal of Agricultural Economics* 95(2):289-295.

Chen, L.-J., C. Ye, S.-W. Hu, V. Wang, and J. Wen. 2013. “The Effect of a Target Zone on the Stabilization of Agricultural Prices and Farmers’ Nominal Income.” *Journal of Agricultural and Resource Economics* 38(1):34-47.

Chu, K.Y., and T.K. Morrison. 1984. “The 1981-82 Recession and Non-Oil Primary Commodity Prices.” Staff Paper, International Monetary Fund 31(1):93-140.

Cooper, R.L. 1980. “The Energy-Economy Connection: 1974-1979 and Beyond.” *Business Economics* 15(4):5-11.

Cunado, J., and F. Perez de Gracia. 2005. “Oil Prices, Economic Activity and Inflation: Evidence for Some Asian Countries.” *The Quarterly Review of Economics and Finance* 45(1):65-83.

de Gorter, H., D. Drabik, and D.R. Just. 2013. “How Biofuels Policies Affect the Level of grains and Oilseed Prices: Theory, Models and Evidence.” *Global Food Security* 2(2):82-88.

__________ 2015. *The Economics of Biofuel Policies*. New York: Palgrave Macmillan Co.

de Gorter, H., D. Drabik, D.R. Just, and E.M. Kliauga. 2013. “The Impact of OECD Biofuels Policies on Developing Countries.” *Agricultural Economics* 44(4-5):477-486.

de Gorter, H., and D.R. Just. 2010. “The Social Cost and Benefits of Biofuels: The intersection of Environmental, Energy and Agricultural Policy.” *Applied Economic Perspectives and Policy* 32(1):4-32.

Devadoss, S., and W.H. Meyers. 1987. “Relative Prices and Money: Further Results for the United States.” *American Journal of Agricultural Economics* 69(4):838-842.

Dornbusch, R. 1976. “Expectations and Exchange Rate Dynamics.” *Journal of Political Economy* 84(6):1161-1176.

Dotsey, M., and M. Reid. 1992. “Oil Shocks, Monetary Policy, and Economic Activity.” *Federal Reserve Bank of Richmond Economic Review* 78:14-27.

Drabik, D., P. Ciaian, and J. Pokrivčák. 2016. “The Effect of Ethanol Policies on the Vertical Price Transmission in Corn and Food Markets.” *Energy Economics* 55:189-199.

Elobeid, A., S. Tokgoz, D.J. Hayes, B.A. Babcock, and C.E. Hart. 2007. “The Long-Run Impact of Corn-Based Ethanol on the Grain, Oilseed, and Livestock Sectors with Implications for Biotech Crops.” *AgBioForum* 10(1):11-18.

Enders, W. 2015. *Applied Econometric Time Series*, 4th. ed. New Jersey: John Wiley & Sons, Inc.

Fischer, S. 2016. “Monetary Policy, Financial Stability, and the Zero Lower Bound.” *The American Economic Review* 106(5):39-42.

Frankel, J.A. 1984. “Commodity Prices and Money: Lessons from International Finance.” *American Journal of Agricultural Economics* 66(5):560-566.

__________1986a. “Expectations and Commodity Price Dynamics: The Overshooting Model.” *American Journal of Agricultural Economics* 68(2):344-348.

__________1986b. “Overshooting Agricultural Commodity Markets and Public Policy: Discussion.” *American Journal of Agricultural Economics* 68(2):418-419.

__________2008. “The Effect of Monetary Policy on Real Commodity Prices.” In J.Y. Campbell, ed. *Asset Prices and Monetary Policy*. Chicago IL: University of Chicago Press, pp. 291-333.

Fuss, M.A. 1977. “The Demand for Energy in Canadian Manufacturing.” *Journal of Econometrics* 5:89-116.

Gilbert, C.L. 2010. “How to Understand High Food Prices.” *Journal of Agricultural Economics* 61(2):398–425.

__________1989. “The Impact of Exchange Rates and Developing Country Debt on Commodity Prices.” *Economic Journal* 99(397):773-784.

Griffin, J.M., and P.R. Gregory. 1976. “An Intercountry Translog Model of Energy Substitution Responses.” *American Economic Review* 66(5):845-857.

Hansen, P.R. 2003. "Structural Changes in the Cointegrated Vector Autoregressive Model." *Journal of Econometrics* 114(2):261-295.

Hertel, T.W., and J. Beckman. 2012. "Commodity Price Volatility in the Biofuel Era: An Examination of the Linkage between Energy and Agricultural Markets." In J. S. Graff Zivin, and J. M. Perloff, ed. *The Intended and Unintended Effects of US Agricultural and Biotechnology Policies*. Chicago, IL: University of Chicago Press, pp. 189-221.

Hochman, G. 2014. "Biofuels at a Crossroads." *Choices*, 29(1). Available online: https://goo.gl/xhhBza

Hochman, G., D. Rajagopal, and D. Zilberman. 2011. "The Effect of Biofuels on Crude Oil Markets." *Applied Economic Perspectives and Policy* 33(1):402-427.

Hooker, M.A. 1996. "What Happen to the Oil Price-Macroeconomy relationship?" *Journal of Monetary Economics* 38:195-213.

Hu, S.-W., L.-J. Chen, V. Wang, M.-Y. Tai, L.-J. Lu, and C.-Y. Lin. 2015. "Energy Policies and Food Prices." *Journal of Economics and Management* 11(1):47-68.

Huang, J., J. Yang, S. Msangi, S. Rozelle, and A. Weersink. 2012. "Biofuels and the Poor: Global Impact Pathways of Biofuels on Agricultural Markets." *Food Policy* 37(4):439-451.

Hudson, E.A., and D.W. Jorgenson. 1974. "U.S. Energy Policy and Economic Growth, 1975-2000." *The Bell Journal of Economics and Management Science* 5(2):461-514.

Johansen, S. 1991. "Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models." *Econometrica* 59(6):1551-1580.

Jorgenson, D.W. 1978. "The Role of Energy in the U.S. Economy." *National Tax Journal* 31(3):209-220.

Kilian, L. 2008. "The Economic Effects of Energy Price Shocks." *Journal of Economic Literature* 46(4):871-909.

Kilian, L., and C. Vega. 2011. "Do Energy Prices Respond to U.S. Macroeconomic News? A Test of the Hypothesis of Predetermined Energy Prices." *The Review of Economics and Statistics* 93(2):660-671.

Knittel, C.R., and R.S. Pindyck. 2016. "The Simple Economics of Commodity Price Speculation." *American Economic Journal: Macroeconomics* 8(2):85–110.

Lai, C.-C., S.-W. Hu, and C.-P. Fan. 2005. "The Overshooting Hypothesis of Agricultural Prices: The Role of Asset Substitutability." *Journal of Agricultural and Resource Economics* 30(1):128-150.

Lai, C.-C., S.-W. Hu, and V. Wang. 1996. "Commodity Price Dynamics and Anticipated Shocks." *American Journal of Agricultural Economics* 78(4):982-990.

MacKinnon, J.G., A.A. Haug, and L. Michelis. 1999. "Numerical Distribution Functions of Likelihood Ratio Tests for Cointegration." *Journal of Applied Econometrics* 14(5):563-577.

McPhail, L.L., and B.A. Babcock. 2012. "Impact of US Biofuel Policy on US Corn and Gasoline Price Variability." *Energy* 37(1):505-513.

Medlock, K.B. 2009a. "Energy Demand Theory." In J. Evans and L. C. Hunt, ed. *International Handbook on the Economics of Energy*. Cheltenham UK and Northampton MA: Edward Elgar Pub, pp. 89-111.

__________2009b. “The Economics of Energy Supply.” In J. Evans and L. C. Hunt, ed. *International Handbook on the Economics of Energy*. Cheltenham UK and Northampton MA: Edward Elgar Pub, pp. 51-72.

Miranowski, J. 2014. “Technology Forcing and Associated Costs and Benefits of Cellulosic Ethanol.” *Choices*, 29(1). Available online: https://goo.gl/3Hna9o

Mork, K.A. 1989. “Oil and the Macroeconomy When Prices Go Up and Down: An Extension of Hamilton's Results.” *Journal of Political Economy* 97(3):740-744.

Moschini, G., H. Lapan, and H. Kim. 2017. “The Renewable Fuel Standard in Competitive Equilibrium: Market and Welfare Effects.” *American Journal of Agricultural Economics* 99(5): 1117-1142.

Mueller, S.A., J.E. Anderson, and T.J. Wallington. 2011. “Impact of Biofuel Production and Other Supply and Demand Factors on Food Price Increases in 2008.” *Biomass and Bioenergy* 35(5):1623-1632.

Myers, R.J., S.R. Johnson, M. Helmar, and H. Baumes. 2014. “Long-Run and Short-Run Co-Movements in Energy Prices and the Prices of Agricultural Feedstocks for Biofuels.” *American Journal of Agricultural Economics* 96(4): 991-1008.

Naylor, R.L., A. Liska, M.B. Burke, W.P. Falcon, J.C. Gaskell, S.D. Rozelle, and K.G. Cassman. 2007. “The Ripple Effect: Biofuels, Food Security, and the Environment.” *Environment* 49(9):30-43.

Nicholson, W. 1978. *Microeconomic Theory: Basic Principles and Extensions*. Hinsdale: The Dryden Press.

Obstfeld, M. 1986. “Overshooting Agricultural Commodity Markets and Public Policy: Discussion.” *American Journal of Agricultural Economics* 68(2):420-421.

Orden, D., and P.L. Fackler. 1989. “Identifying Monetary Impacts on Agricultural Prices in VAR Models.” *American Journal of Agricultural Economics* 71(2):495–502.

Orden, D., and C. Zulauf. 2015. “Political Economy of the 2014 Farm Bill.” *American Journal of Agricultural Economics* 97(5):1298–1311.

Perez, S.J., and M.V. Siegler. 2006. “Agricultural and Monetary Shocks before the Great Depression: A Graph-Theoretic Causal Investigation.” *Journal of Macroeconomics* 28(4):720-736.

Pindyck, R.S. 1979. “Interfuel Substitution and the Industrial Demand for Energy: An International Comparison.” *The Review of Economics and Statistics* 61(2):169-179.

Rathmann, R., A. Szklo, and R. Schaeffer. 2010. “Land Use Competition for Production of Food and Liquid Biofuels: An Analysis of the Arguments in the Current Debate.” *Renewable Energy* 35(1):14-22.

Rausser, G.C., J.A. Chalfant, and K.G. Stamoulis. 1985. “Instability in Agricultural Markets: the U.S. Experience.” Working paper 493, Department of Agricultural & Resource Economics, University of California, Berkeley.

Roberts, M.J., and W. Schlenker. 2013. “Identifying Supply and Demand Elasticities of Agricultural Commodities: Implications for the US Ethanol Mandate.” *American Economic Review* 103(6):2265-2295.

Saghaian, S.H. 2010. “The Impact of the Oil Sector in Commodity Prices: Correlation or Causation?” *Journal of Agricultural and Applied Economics* 42(3):477-485.

Saghaian, S.H., M.F. Hasan, and M.R. Reed. 2002. “Overshooting of Agricultural Prices in Four Asian Economies.” *Journal of Agricultural and Applied Economics* 34(1):95-109.

Saghaian, S., M. Nemati, C. Walters, and B. Chen. 2018. "Asymmetric Price Volatility Transmission between U.S. Biofuel, Corn, and Oil Markets." *Journal of Agricultural and Resource Economics* 43(1):46-60.

Saghaian, S.H., M.R. Reed, and M.F. Hasan. 2006. "Monetary Policy Impacts on US Livestock-Oriented Agricultural Prices." *Progress in Economic Research* 9:45-62.

Saghaian, S.H., M.R. Reed, and M.A. Marchant. 2002. "Monetary Impacts and Overshooting of Agricultural Prices in an Open Economy." *American Journal of Agricultural Economics* 84(1):90-103.

Schuh, G.E. 1974. "The Exchange Rate and U.S. Agriculture." *American Journal of Agricultural Economics* 56(1):1-13.

Scrimgeour, D. 2014. "Commodity Price Responses to Monetary Policy Surprises." *American Journal of Agricultural Economics* 97(1):88-102.

Shapiro, M.D., and M.W. Watson. 1988. "Sources of Business Cycle Fluctuations." *NBER Macroeconomics Annual* 3:111-148.

Sorrell, S. 2015. "Reducing Energy Demand: A Review of Issues, Challenges and Approaches." *Renewable and Sustainable Energy Reviews* 47:74-82.

Stamoulis, K.G., and G.C. Rausser. 1987. "Overshooting of the Agricultural Prices." Working paper 493, Department of Agricultural & Resource Economics, University of California, Berkeley.

Tai, M.Y., C.C. Chao, S.W. Hu, C.C. Lai, and V. Wang. 2014. "Monetary Policy and Price Dynamics in a Commodity Futures Market." *International Review of Economics & Finance* 29:372-379.

Taylor, J.S., and J. Spriggs. 1989. "Effects of the Monetary Macro-economy on Canadian Agricultural Prices." *The Canadian Journal of Economics* 22(2):278-289.

Timilsina, G.R., S. Mevel, and A. Shrestha. 2011. "World Oil Price and Biofuels A General Equilibrium Analysis." Working paper 5673, The World Bank.

Townsend, T. 2015. "The 2014 U.S. Farm Bill and Cotton: Proof that the WTO Matters." *Choices*, 30(2). Available online: https://goo.gl/7BcSL6

Tyner, W.E. 2010. "The Integration of Energy and Agricultural Markets." *Agricultural Economics* 41(s1):193-201.

Tyner, W.E., and F. Taheripour. 2007. "Renewable Energy Policy Alternatives for the Future." *American Journal of Agricultural Economics* 89(5):1303-1310.

U.S. Environmental Protection Agency. 2007. *The Plain English Guide to the Clean Air Act*. Washington DC.

U.S. House. 113th Congress, 2nd Session. *H.R. 2642, Agricultural Act of 2014*. Washington, Government Printing Office, 2014.

Weyman-Jones, T. 2009. "The Theory of Energy Economics: An Overview." In J. Evans and L. C. Hunt, ed. *International Handbook on the Economics of Energy*. Cheltenham UK and Northampton MA: Edward Elgar Pub, pp. 20-50.

Whistance, J., and W. Thompson. 2014. "A Critical Assessment of RIN Price Behavior and the Implications for Corn, Ethanol, and Gasoline Price Relationships." *Applied Economic Perspectives and Policy* 36(4):623-642.

Zilberman, D., G. Hochman, S. Kaplan, and E. Kim. 2014. "Political Economy of Biofuel." *Choices*, 29(1). Available online: https://goo.gl/ko9o6a

Zilberman, D., G. Hochman, D. Rajagopal, S. Sexton, and G. Timilsina. 2013. "The Impact of Biofuels on Commodity Food Prices." *American Journal of Agricultural Economics* 95(2):275-281.

Zulauf, C., and D. Orden. 2016. "80 Years of Farm Bills—Evolutionary Reform." *Choices*, 31(4). Available online: https://goo.gl/hXwfHu

Vita

Mahdi Asgari

Education

Ph.D., Agricultural Economics, University of Kentucky expected 2018
Dissertation: "The Impact of Biofuel Policies on Overshooting of Agricultural Prices."
(Chair: Dr. Sayed Saghaian Co-Chair: Dr. Michael Reed)

M.S., Economics, University of Kentucky	2015
M.S., Agricultural Economics, University of Tehran, Iran	2009
B.S., Agricultural Economics, Shiraz University, Iran	2006

Research Experience

Graduate Research Assistant, Department of Agricultural Economics University of Kentucky	2011 - 2017
Visiting Student Researcher, Department of Agricultural and Resource Economics University of California-Berkeley	May - July 2016

Grants

Tim Woods, Melissa Newman, Yuqing Zheng, Samane Zarebanadkoki, Whitney Crume, Mahdi Asgari, and Patrick Bello. $8250, 2017-2018. "Locally Sourced Ingredients in Craft Soda Production: Consumer Preferences and the Economic Impacts." Food Connection at UK Student Opportunity Grant.

Academic Awards (University of Kentucky)

Outstanding Service Award, Graduate Student Congress,	2018
Cross-Cultural Understanding Award, International Center,	2013

Publications

Shokoohi, Z., A.H. Chizari, and M. Asgari. 2018. "Investigating Bargaining Power of Farmers and Processors in Iran's Dairy Market." Journal of Agricultural and Applied Economics (forthcoming, 2018).

Zuo, N., J. Penn, and M. Asgari. 2018. "Teaching as a Graduate Student: A One-credit Teaching Module Case." NACTA Journal (forthcoming, 2018)

Asgari, M., and L. Nogueira. 2015. "Institutional Differences and Agricultural Performance in Sub-Saharan Africa." Journal of International Agricultural Trade and Development 9(2):189-209.

Asgari, M., and S.H. Saghaian. 2013. "Oligopolistic Market Structure in the Japanese Pistachio Import Market." Journal of Agricultural & Food Industrial Organization 11(1):87-99.

Presentations

Asgari, M., M. Nemati and Y. Zheng. "Nowcasting Food Stock Movement using Food Safety Related Web Search Queries." February 2-6, 2018, Annual Meeting of Southern Agricultural Economics Association, Jacksonville, FL.

Asgari, M., and Y. Zheng. “The Structure and Competitiveness of Energy Drinks Market.” July 31-August 2, 2016, Annual Meeting of the Agricultural and Applied Economics Association, Boston, MA.

Asgari, M. “U.S. Food Manufacturing Industry: The Choice of Exports vs. FDI.” February 6-9, 2016, Annual Meeting of Southern Agricultural Economics Association, San Antonio, TX.

Asgari, M., and M.R. Reed. “Terms of Trade Volatility and Persistence to Shocks in the United States.” July 26-28, 2015, Joint Annual Meeting of the Agricultural and Applied Economics Association and the Western Agricultural Economics Association, San Francisco, CA.

Asgari, M., and M.R. Reed. “Trends in United States - China Commodity Terms of Trade: A Case of Heterogeneous Goods.” December 13-14, 2014, 8th biennial meetings of Hong Kong Economic Association, Shandong, China.

Asgari, M., and L. Nogueira. “Institutional Differences and Agricultural Performance in Sub-Saharan Africa.” August 4-6, 2013, Joint Annual Meeting of the Agricultural and Applied Economics Association and the Canadian Agricultural Economics Society, Washington, DC.

Asgari, M., and S.H. Saghaian. “Oligopolistic Structure in the Japanese Pistachio Import Market.” February 2-5, 2013, Annual Meeting of Southern Agricultural Economics Association, Orlando, FL.

Teaching Experience (University of Kentucky)

Economic and Business Statistics	Fall 2016
World Food Needs and U.S. Trade in Agriculture Products	Fall 2015
Food Policies and Related Issues	Spring 2014
Agricultural Financial Management	Spring 2014 & 2015
Advanced Agricultural Marketing	Fall 2013
Advanced Quantitative Methods in Agricultural Economics	Spring 2013
Agribusiness Management	Spring 2013

Academic Service (University of Kentucky)

Member, search committee for Vice President of Institutional Diversity	2016-2017
Member, Graduate Council, Graduate School	2015-2016
Member, Graduate Curriculum Committee College of Agriculture, Food and Environment,	2013-2014
President/Vice-President, Ag. Econ. Graduate Student Organization	2013-2015
Treasurer, Iranian Student Association	2013-2014