Copper Price Shocks and the Business Cycle of the Chilean Economy

by

Jesse Thomas Lassiter

Advisor: Javier Reyes
An Honors Thesis in partial fulfillment of the requirements for the Bachelor of Science in Business Administration in Economics

Sam M. Walton College of Business
University of Arkansas
Fayetteville, Arkansas

May 14, 2011

Table of Contents

Introduction

The influence of commodity shocks on real business cycles has been an issue of debate for many years. With long-term commodity price declines and erratic short-term price movements, commodity shocks can influence fiscal and macroeconomic stability (Problems and Policy Challenges faced by Commodity-Dependent Developing Countries (CDDCs), 2005). Although commodity shocks can influence the macroeconomic stability of any country, developing countries are particularly susceptible due to their increased dependence on commodities.

In particular, many developing countries are very dependent on commodity exports (Page, 2001). For instance, Chile is very dependent on copper. In 2006, copper composed 56.6 percent of Chile's exports and approximately 13 percent of nominal GDP (Ruiz-Dana, 2007). With copper comprising such a large portion of Chile's output, Chile may be particularly susceptible to volatility in the price of copper.

Depending on the commodity and the economy in question, the commodity may have either a symmetric relationship or an asymmetric relationship with output. According to Sichel (1993), an asymmetric cycle can be defined as "one in which some phase of the cycle is different from the mirror image of the opposite phase." For this instance, some characteristic of the expansionary phase of the business cycle is different than the corresponding characteristic of the recessionary phase. The Merriam-Webster Dictionary defines a commodity as "a product of agriculture or mining," or more generally "an economic good." Examples of commodities include oil, minerals, and corn.

With this in mind, the goal of this research paper is to determine if there is an asymmetric relationship between copper prices and the Chilean business cycle. The methodology used will be directly adapted from both Hamilton (1989) and Holmes & Wang (2003). The Markov regime-switching approach will be used to construct a business cycle model that incorporates the transition probabilities between two states of nature. With the resulting transition probabilities, it will be possible to determine if such an asymmetric relationship between copper prices and the Chilean business cycle exists.

Determining the existence of this relationship will increase the amount of information available to the Central Bank of Chile. This should increase the precision of monetary policy decisions, resulting in reduced volatility of the business cycle. Subsequently, this increase in precision will foster more stable economic growth.

Methodologies From Previous Studies

Among the many commodities present in every economy, the most extensive research has been focused on oil. To gain a better understanding of the relationships between commodities and output, a review of the research focused on oil and its related shocks is in order. After this initial review of commodity shocks with a focus on oil, it is then possible to expand the review of commodity shocks to include other commodities.

Ferderer (1996) describes three methods through which oil prices can exhibit a symmetric relationship with respect to the business cycle: a real balance effect, an income transfer channel, and a potential output channel. There are also many asymmetric relationships that are observed between oil prices and business cycles. Such a relationship might occur in response to counter-inflationary policies set in place by governments in response to oil price shocks (Ahmed et al., 1988). Bernanke (1983) and Pindyck (1991) also indicate that an asymmetric relationship between oil prices and the business cycle may occur when firms postpone irreversible investment decisions due to increased oil price uncertainty. Lilien (1982) and Loungani (1986) suggested that a relationship may be explained by the hypothesis that aggregate unemployment may rise when the volatility of the price of oil increases.

One very effective method of determining if asymmetric relationships exist is the application of the Markov regime-switching approach. This approach allows the researcher to incorporate the transition probabilities between two states of nature into the business cycle model. It allows for the model to include the recursive nature of the economy (McCandles, 2008). Markov chains also allow the determination of the long-run transition probabilities of an economy regardless of the initial state of the economy.

When applying the Markov regime-switching approach, it is important to compare the probability of remaining in an expansionary phase of the business cycle versus the probability of remaining in a recessionary phase of the business cycle. If the magnitude of these two probabilities is significantly different, then the variable influencing the transition probabilities has an asymmetric relationship with the business cycle. In essence, the variable influences the expansionary phase of the business cycle differently than it influences the recessionary phase of the business cycle.

Determining if such relationships exist can be very difficult, and such determinations often include mathematically intensive approaches. In an interesting U.S. study, Hamilton (1989) further developed this process and its applications. Hamilton used a first-order Markov process to model the changes in output between two different states of production, identifying the existence of asymmetries observable in the U.S. He found that this approach accurately models the shifts between positive and negative output growth displayed in the National Bureau of Economic Research chronology of business cycle peaks and troughs.

Raymond & Rich (1997) built on the model proposed by Hamilton (1989). Instead of using the basic model proposed by Hamilton (1989) in which the transition probabilities of switching between expansionary phases and recessionary phases of the business cycle are held constant, Raymond & Rich allowed the transition probabilities to depend on lagged real oil prices. By incorporating this addition to the model, Raymond & Rich determined that "oil price movements predominantly impact the mean of low-growth phases of output rather than the transitional probabilities between growth phases."

Holmes & Wang (2003) also applied the approach described by Hamilton (1989) to determine if an asymmetric relationship exists between oil prices and output in the U.K. economy. They incorporated the price of oil into the transition probabilities of switching between expansionary phases and recessionary phases of the business cycle. Holmes & Wang determined that oil price shocks exert mean-dependent effects associated with expansionary phases and recessionary phases of the business cycle. This relationship was asymmetric because the duration of the expansionary phase of the business cycle is adversely related to the price of oil.

While most economies are affected by volatility in oil prices, each country also contains other factors and commodities that influence their business cycle. Misas & Ramirez (2006) applied a similar approach as that of Holmes & Wang (2003) in a study focusing on the Columbian economy and certain explanatory variables, including government expenditures, terms of trade, and capital outflows. Misas & Ramirez compared the transition probabilities between a fixed transition probabilities (FTP) Markov regime switching model and a time-varying transition probabilities (TVTP) Markov regime switching model. The FTP model was rejected in favor of the TVTP model due to a marked difference between the resulting probabilities, indicating that the explanatory variables are important factors in determining the state of the economy. Misas & Ramirez concluded that the probability of remaining in a period of sustainable growth increases with a rise in the terms of trade, and it decreases with a rise in government expenditures. An increase in capital outflows, on the other hand, increases the probability of being in a depression.

According to Mejia-Reyes (2000), the business cycle observed in Chile is largely independent from the other business cycles observed throughout Latin America. In 2006, copper comprised 56.6 percent of Chile's exports and approximately 13 percent of nominal GDP (Ruiz-Dana, 2007). This indicates that copper, as a commodity, has the potential to exert significant influence on Chile's business cycle.

Medina & Soto (2006) began to examine the impact of copper-price shocks on the business cycle of Chile. Their study used a dynamic stochastic general equilibrium (DSGE) model to analyze the impulse response functions to copper price shocks. Medina & Soto then compared the results from the impulse response functions under different fiscal rules. They indicated that copper price shocks have less impact on GDP after the year 2000, primarily due to the policy change of the government from using a fully flexible exchange rate regime to using a structural fiscal rule. They also determined several values for impacts in the business cycle given very specific constraints. Although several studies of commodity prices and the Chilean business cycle have been conducted, the Markov regime-switching approach has not yet been applied to determine the existence of such an asymmetric relationship between copper prices and the Chilean business cycle.

Data and Methodology

For this study, I employ quarterly data for the period 1988-2009. The data for the Consumer Price Index (CPI) and the Chile:U.S. exchange rate (CLP:USD) have been retrieved from the Central Bank of Chile. The data for copper prices and Chile's real GDP have been retrieved from Bloomberg. The output growth rate, denoted Δy, is constructed by taking the first natural logarithmic difference of Chilean quarterly real GDP and multiplying by 100. The real price of copper is constructed by the following formula:

$$real\ price\ of\ copper = \frac{nominal\ \$\ copper\ price \times nominal\ CLP{:}USD\ exchange\ rate \times 100}{CPI}$$

The method primarily used to calculate oil price shocks is the first natural logarithmic difference of the real price of oil (Hooker, 1996). Hamilton (1996) voices his concern with this method. When using this method, all increases in the price of oil could be considered an oil price shock. However, some increases in the price of oil can be the market's correction of a temporary decrease in the price of the oil in the preceding quarter. These correctional increases may not affect the economy in the same manner as increases not attributed to a correction by the market. Therefore, Hamilton proposes "to compare the current price of oil with where it has been over the previous year rather than during the previous quarter." With Hamilton's recommendation in mind, we calculate copper price shocks as the first natural logarithmic difference of the real price of copper from the maximum of the previous four quarters. If there has not been an increase from the maximum of the previous four quarters, we consider the copper price shock to be equal to zero. We will denote the variable representing copper price shocks as Δo^{+}.

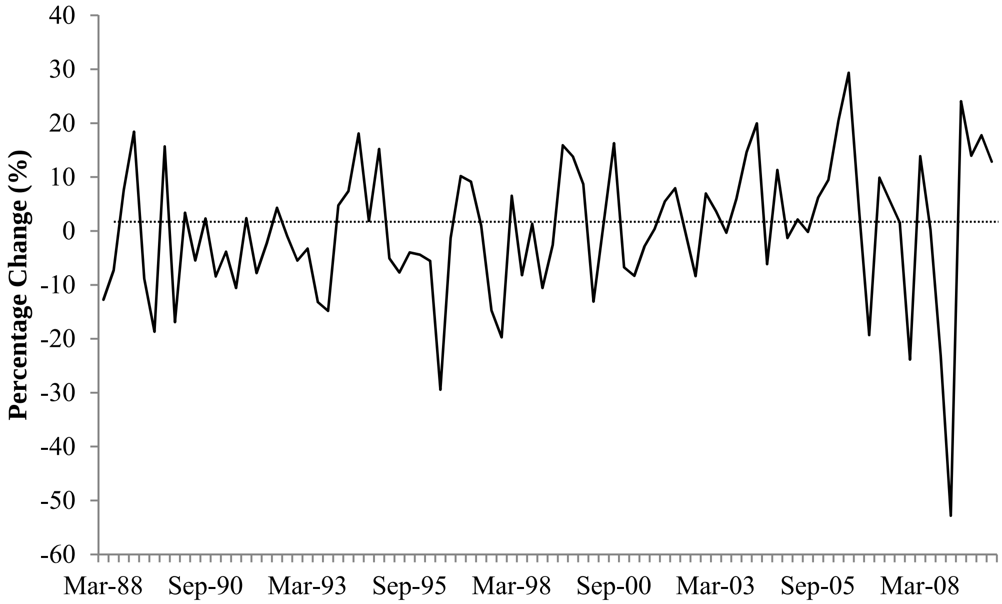

Figure 1: First natural logarithmic difference in real price of copper over the previous quarter.

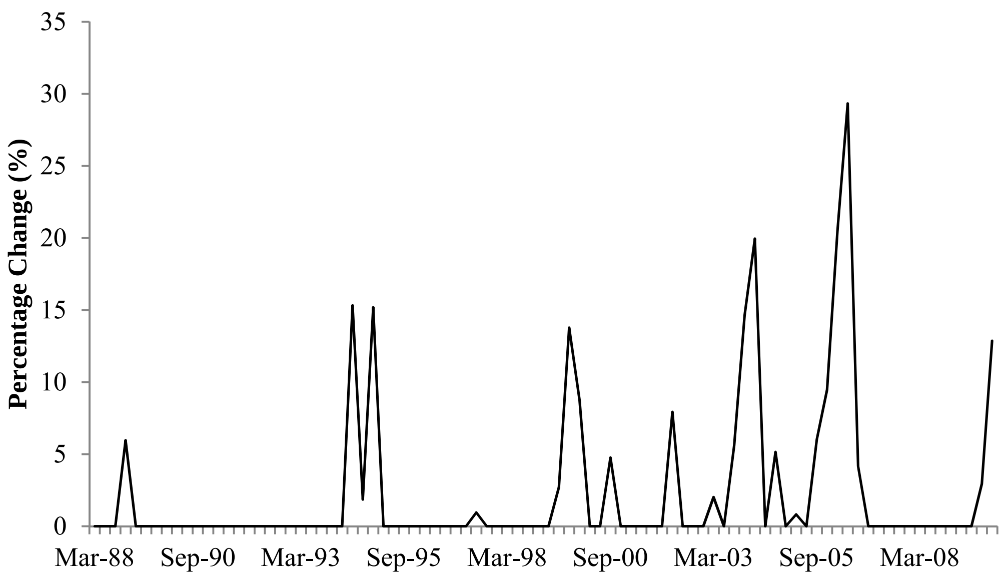

Figure 2: First natural logarithmic difference in the real price of copper over the maximum of the previous four quarters if positive, zero otherwise (Δo^{+}).

Figures 1 and 2 above show the difference in the calculation of copper price shocks using the first natural logarithmic difference and the approach described by Hamilton (1996), respectively. When using this technique, a considerable number of conventional copper price shocks are no longer considered, leaving only those copper price shocks not attributable to market corrections.

The estimating model used for this study is based on Hamilton's Markov switching model and closely follows the model used by Holmes & Wang (2003). To represent the state of the economy at time t, create a discrete random variable S_t, where $S_t = (0,1)$ with 0 representing a recession and 1 representing an expansion. The expected growth rate of GDP can then be represented by the following equation that takes into account the current state of the economy:

$$E(\Delta y_t|S_t) = \mu(S_t) = \begin{cases}\mu_0 + \epsilon_t \\ \mu_1 + \epsilon_t\end{cases} \tag{1}$$

In this equation, μ_0 is the expected value of the growth rate during a recession and μ_1 is the expected value of the growth rate during an expansion. S_t is an indicator variable that evolves according to a first-order Markov switching model in which the value of S_t at a certain time cannot be known with certainty. The following transition probabilities are also dependent on the state of the economy, as specified by Hamilton (1989):

$$\begin{aligned}
&P[S_t = 1|S_{t-1} = 1] = p \\
&P[S_t = 1|S_{t-1} = 0] = 1 - p \\
&P[S_t = 0|S_{t-1} = 0] = q \\
&P[S_t = 0|S_{t-1} = 1] = 1 - q \\
&0 < p < 1, \quad 0 < q < 1
\end{aligned} \tag{2}$$

In these equations, *p* and *q* are fixed transition probabilities of being in expansions and recessions, respectively. This means that the transition probabilities are considered constant throughout time, regardless of the other events that might be occurring in the economy.

The effects of copper price shocks on the deepness of the business cycle are incorporated into Equation (1) as follows (Raymond & Rich, 1997):

$$[\Delta y_t - \mu(S_t)] = \sum_{i=1}^{k} \beta_i \Delta o_{t-i}^{+} + \epsilon_t \qquad \epsilon_t \sim i.i.d.N(0, \sigma_\epsilon^2) \tag{3}$$

For this study, we will estimate Equation (3) using k = 4. Before the estimation of the model, we might expect the value of $\beta_i > 0$, indicating that copper price shocks have a positive impact on the growth of Chilean real GDP.

To estimate Equation (3), Perlin (2010) recommends using the following two-step process with the MS_Regress package in MATLAB:

Step 1: Estimate the following using the MS_Regress_Fit function in MATLAB:

$$E(\Delta y_t | S_t) = \mu(S_t) = \begin{cases} \mu_0 + \epsilon_t \\ \mu_1 + \epsilon_t \end{cases}$$

$$\epsilon_t \sim N(0, \sigma^2)$$

$$S_t = 1, 2 \tag{4}$$

Step 2: Retrieve the residuals vector of the dependent variable ($\hat{\epsilon}_t$) and regress it on k lagged variables:

$$\hat{\epsilon}_t = \sum_{i=1}^{k} \beta_i \Delta o_{t-i}^{+} + v_t$$

$$v_t \sim N(0, \sigma_{v_t}^2) \tag{5}$$

Although this approximation method does not yield exact result, the resulting approximation should be comparable (Perlin, 2010).

The analysis of the role of copper price shocks on the growth rate of Chilean GDP will be based on the following two models, showing the restrictions placed on the equations above:

Model I: Hamilton Markov switching model

$$\beta_1 = \ldots = \beta_k = 0$$

Under the restrictions of this model, copper price shocks do not play a role in the mean equation for output. This model uses a Markov switching approach to construct the expected output growth rate depending on the state of the economy, regardless of copper price shocks.

Model II: Hamilton Markov switching model + Mean model

$$\beta_1 \neq \ldots \neq \beta_k \neq 0$$

In this model, copper price shocks enter the mean equation for output. This model includes four lagged variables to incorporate the effects of copper price shocks on the expected output growth rate.

It is first prudent to determine if Model I accurately estimates the expected output growth rate. Then, by comparing and contrasting the two models above, it is possible to determine whether copper price shocks significantly influence the expected output growth rate.

Results

Model I serves as the base model as described by Hamilton (1989). This model indicates that the expected output growth rate evolves according to the corresponding regime with a growth estimate of approximately 1.52% during expansions and approximately -0.85% during recessions, as shown in Table 1. The estimated growth rate during expansions is statistically significant at the 1% level. The estimated growth rate during recessions, however, is not significant at the 10% level. The level of confidence would have to be relaxed to the 15% level for the estimated growth rate during recessions to be considered significant. This indicates that there is not significant evidence that μ_0 does not equal zero, suggesting that the output growth rate during recessions may not differ from zero.

Table 1: Maximum Likelihood estimates of the two models.

Parameter	Model I	Model II
μ_0	-0.845 (0.38)*	-0.845 (0.38)*
μ_1	1.520 (0.14)**	1.520 (0.14)**
β_1		-0.003 (0.03)
β_2		0.011 (0.04)
β_3		0.018 (0.04)
β_4		-0.009 (0.03)
p	0.96 (0.10)**	0.96 (0.10)**
q	0.61 (0.16)**	0.61 (0.16)**
LL	-155.207	-150.240

Notes: Standard errors are reported in parenthesis next to the corresponding values. * indicates that the value is significant at the 5% level, and ** indicates that the value is significant at the 1% level. LL stands for the log likelihood, with the LL of Model II corresponding to the LL of the corresponding regression. Model II is estimated with $[\Delta y_t - \mu(S_t)] = \sum_{i=1}^{4} \beta_i \Delta o_{t-i}^{+} + \epsilon_t$

As shown in Table 1, the probability of remaining in an expansion is approximately 96%, and the probability of remaining in a recession is approximately 61%. Both probabilities are significant at the 1% level. The average duration of an expansion can be calculated by $(1 - p)^{-1}$, and the average duration of a recession is similarly calculated by $(1 - q)^{-1}$. This indicates that the average expansion and recession lasts 24.1 quarters and 2.5 quarters, respectively.

Model II attempts to explain some of the remaining variance from Model I. In other words, Model II uses copper prices shocks to explain the differences between the expected output growth rate and the observed output growth rate in Model I. Because the approximation technique used to estimate Model II is a two step process (with step one being the approximation of Model I), the estimated output growth rates and the corresponding transition probabilities remain the same. The addition of Model II in the analysis is the regression of the residuals from Model I over four lagged copper price variables.

As shown in Table 1, the coefficients of the lagged copper price variables, β_1 ... β_4, are -0.003, 0.011, 0.018, and -0.009, respectively. None of these variables are statistically significant at the 10% level. This indicates that the copper price shock variables fail to explain the variance of the output growth rate from its expected rate. The R-square of the regression is only 0.007. This also indicates that the lagged copper price shock variables fail to explain the variance.

There are several possible explanations for the failure of the lagged copper price variables to explain a significant portion of the variance from Model I. The first explanation is that the methods used in the analysis above are insufficient in capturing the relationship between copper price shocks and the Chilean business cycle. Several avenues for future research are discussed below that might allow for a more accurate analysis of the relationship. Although the avenues discussed below may prove successful in capturing the relationship between copper price shocks and the Chilean business cycle, the approaches are beyond the scope of this research project and are left for possible future research.

On the other hand, it is possible that copper price shocks do not have a significant effect on the Chilean business cycle. Although Holmes & Wang (2003) and Raymond & Rich (1997) found asymmetric relationships between oil price shocks and the business cycles of the U.K. and the U.S., respectively, it does not directly translate that copper price shocks must have an asymmetric relationship with the Chilean business cycle. The first reason is that both the U.K. and the U.S. have fully developed economies while Chile's economy is still developing. This can have a profound impact on the inner workings of different markets as well as the extent to which the economy is dependent on the commodity.

The second reason is that the fundamental relationships between oil and the economies of the U.K. and the U.S. may be different than the relationship between copper and economy of Chile. For both the U.K. and the U.S., oil is one of the key inputs for many of the products produced, including such products as pharmaceuticals, plastics, etc. Oil price shocks can also influence other markets indirectly by increasing transportation costs, the price of key inputs, etc. Copper, on the other hand, is primarily an output product for Chile, as shown by the percentage of exports that are attributed to copper (Mejía-Reyes, 2000). Therefore, copper price shocks do not have as broad of an impact on the Chilean economy as oil price shocks have on the U.K.'s economy or the U.S.'s economy.

Avenues for future research

One area of improvement for potential future research would be to compute Model II in one step instead of using the two step approximation. This would involve incorporating the lagged copper price shock variables directly into the computation of the Markov regime switching model. Not only would this be more accurate, but it would allow the log likelihood associated with the model to be used in comparison tests with the other models. This would help to expand the techniques available for analysis and improve the accuracy of the results.

Another area of interest for potential future research is the inclusion of time-varying transition probabilities (TVTP) into the Markov regime switching process. This would be accomplished by the following equations (Raymond & Rich, 1997):

$$P[S_t = 1 | S_{t-1} = 1, \Delta o_t^+, \Delta o_{t-1}^+, \Delta o_{t-2}^+, \ldots] = p_t = \Phi(\delta_0 + \textstyle\sum_{i=0}^{m} \delta_i o_{t-i}^+)$$

$$P[S_t = 0 | S_{t-1} = 0, \Delta o_t^+, \Delta o_{t-1}^+, \Delta o_{t-2}^+, \ldots] = q_t = \Phi(\gamma_0 + \textstyle\sum_{i=0}^{n} \gamma_i o_{t-i}^+) \qquad (6)$$

In these equations, $\Phi(\cdot)$ is the cumulative normal distribution function. This ensures that the transition probabilities, p_t and q_t, lie in the open interval (0,1).

This approach allows a straightforward analysis of the type of influence copper price shocks bear on the Chilean business cycle. If the copper price shocks influence the transition probabilities differently, then it becomes apparent that copper price shocks cause asymmetries in the Chilean business cycle. This approach would allow for the construction of two new models for analysis. The first would demonstrate the effects of copper price shocks on the transition probabilities alone. The second would include the effects of copper price shocks on both the transition probabilities and the mean expected output growth rate. Constructing four models (these two new models and the two presented in this paper) would allow for more detailed analysis. In particular, it would be possible to perform log likelihood tests to determine which models most accurately fit the observed output and copper price shocks.

Conclusion

Two models are used to estimate the expected output growth rate of the Chilean business cycle. Model I is a basic Markov regime switching model as described by Hamilton (1989). There is significant evidence to suggest that Model I is accurate in describing the expected output growth rate during expansions at the 1% level. However, the model is only significant in the case of recessions if the confidence level is relaxed to 15%.

Model II attempts to explain the variance of the observed output growth rate from the expected output growth rate in Model I. When the residuals from Model I are regressed over four lagged copper price shock variables in Model II, there is insufficient evidence to suggest that the copper price shock variables are significant at the 10% level, thus indicating that copper price shocks fail to influence the expected growth rate of output. This could be due to several reasons, including the possibility that the models used in this study are incapable of capturing the relationship between copper price shocks and the Chilean business cycle and the possibility that copper price shocks have no significant relationship with the Chilean business cycle. The latter could be due to the fact that Chile is still a developing country or that copper, as an output product, does not significantly impact a large enough portion of the Chilean economy.

Overall, there is insufficient evidence from this study to suggest that copper price shocks influence the output growth rate of the Chilean business cycle. This also indicates that copper price shocks do not cause asymmetries. While copper continues to play a large role in the

Chilean economy, output growth remains relatively unaffected by fluctuations in the price of Chile's largest export. The analysis of the role of copper price shocks can be analyzed in more depth by modifying the technique used for the approximation of equation (2). Copper price shocks may also influence the transition probabilities directly, thus including time-varying transition probabilities would further expand the analysis of the role of copper price shocks on the Chilean business cycle.

Works Cited

(n.d.). Retrieved October 6, 2010, from Merriam-Webster Dictionary: http://www.merriam-webster.com/dictionary/commodity

Ahmed, E. R. (1988). A Global Model of OECD Aggregate Supply and Demand Using Vector Autoregressive Techniques. *European Economic Review* , 1711-1730.

Bernanke, B. S. (1983). Irreversibility, Uncertainty, and Cyclical Investment. *The Quarterly Journal of Economics* , 85-107.

Ferderer, J. P. (1996). Oil Price Volatility and the Macroeconomy. *Journal of Macroeconomics* , 1-26.

Hamilton, J. D. (1989). A new approach to the economic analysis of nonstationary time series and the business cycle. *Econometrica* , 357-385.

Hamilton, J. D. (1996). This is what happened to the oil price-macroeconomy relationship. *Journal of Monetary Economics* , 215-220.

Holmes, M. J., & Wang, P. (2003). Oil price shocks and the asymmetric adjustment of UK output: A Markov-switching approach. *International Review of Applied Economics* , 181-193.

Hooker, M. A. (1996). What happened to the oil price-macroeconomy relationship? *Journal of Monetary Economics* , 195-213.

Lilien, D. M. (1982). Sectoral Shifts and Cyclical Unemployment. *The Journal of Political Economy* , 777-794.

Loungani, P. (1986). Oil Price Shocks and the Dispersion Hypothesis. *The Review of Economics and Statistics* , 536-540.

McCandles, G. (2008). *The ABCs of RBCs.* Cambridge: Harvard University Press.

Medina, J. P., & Soto, C. (2006, May). Copper Price, Fiscal Policy and Business Cycle in Chile.

Mejía-Reyes, P. (2000). Asymmetries and Common Cycles in Latin America: Evidence from Markov-Switching Models. *Economia Mexicana NUEVA EPOCA* , 189-225.

Misas, M., & Ramirez, M. T. (2006, December). *Columbian economic growth under Markov switching regimes with endogenous transition probabilities.* Retrieved from http://ssrn.com/abstract=953954

Page, S., & and Hewitt, A. (2001). *World commodity prices: Still a problem for developing countries?* London: Overseas Development Institute.

Perlin, M. (2010). MS_Regress - The MATLAB Package for Markov Regime Switching Models. Available at SSRN: http://ssrn.com/abstract=1714016.

Pindyck, R. S. (1991). Irreversibility, Uncertainty, and Investment. *Journal of Economic Literature* , 1110-1149.

Problems and Policy Challenges faced by Commodity-Dependent Developing Countries (CDDCs). (2005, November). Retrieved October 6, 2010, from South Centre: http://www.southcentre.org/index.php?option=com_content&task=view&id=271

Raymond, J. E., & Rich, R. W. (1997). Oil and the Macroeconomy: A Markov State-Switching Approach. *Journal of Money, Credit and Banking* , 193-213.

Ruiz-Dana, A. (2007). *Commodity Revenue Management: The case of Chile's copper boom.* Winnipeg: International Institute for Sustainable Development.

Sichel, D. E. (1993). Business Cycle Asymmetry: A Deeper Look. *Economic Inquiry* , 224-236.