The Impacts of Chinese Exchange Rate Policy

on World Soybean and Products Markets

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ABSTRACT

This study examines the impacts of China's exchange rate policy on commodity market with a lengthy vertical supply chain. By taking the soybean industry as a case, the analysis considers the joint effects of the undervaluation of the RMB/$US exchange rate and the interactions along vertical supply chain relative to prices, supplies, demands, and trade of world soybean and soybean products, In the analysis, the effects of China's monetary policy of RMB undervaluation on world soybean, soybean meal and soybean oil supplies, demands, prices and trade over the 1993/94 through 2012/13 are measured. Simulation results show RMB undervaluation has significant effects on world soybean and soybean products markets. China's monetary policy of RMB undervaluation is likely to increase China's soybean price and reduce China's soybean imports. It is also found that China has borne most of the burden from its own exchange rate undervaluation policy over the years.

Keywords: exchange rate policy, soybean, supply chain, undervaluation

1. Introduction

Following the 1994 devaluation of China's currency, the Renminbi (RMB) or Yuan[3], as the currency is known, was kept at a constant nominal level relative to the U.S. dollar despite numerous U.S. forces that would normally lead to currency appreciation, including China's rapid economic growth, rising productivity, strong and growing exports, and large foreign direct investment inflows (Funke and Rahn 2005). On July 1, 2005, China announced its intention to reform its exchange rate regime and move toward a managed float of the RMB based on market supply and demand with reference to a basket of currencies. At the time, many analysts claimed that the RMB was undervalued against the dollar. Funke and Rahn (2005)

[3] China's currency is officially known as the Renminbi (literally meaning "People's currency") and the Yuan is the basic currency unit. The equivalent for the United States would be "legal U.S. tender" with the "dollar" as the basic currency unit.

concluded that the undervaluation against the dollar was around 15%. Goldstein and Lardy (2003a and 2003b) estimated the undervaluation to be in the range of 15% to 25% while Bergsten (2004) assessed the undervaluation to be more like 20% to 25%.

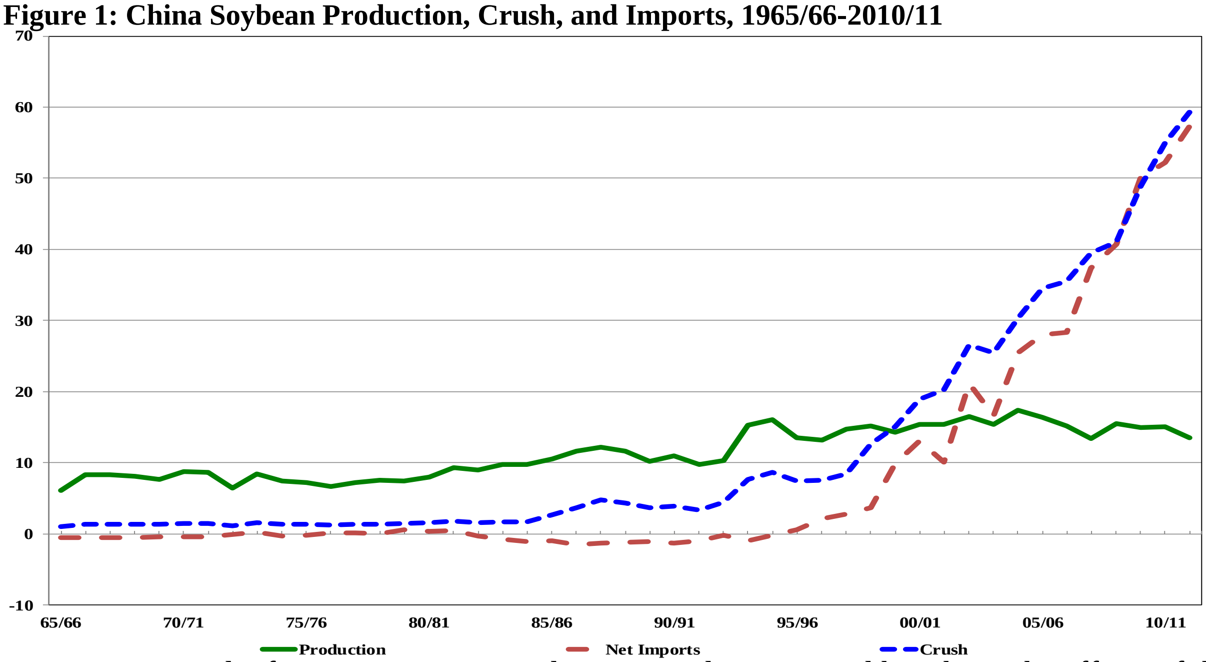
Under the new exchange rate regime, the RMB was allowed to appreciate slowly over the next three years. Then in mid-July 2008, China halted its currency appreciation policy mainly due to declining global demand for Chinese products that resulted from the effects of the global financial crisis (Morrison and Labonte 2013). The RMB/dollar exchange rate was held relatively constant through around mid-June 2010. Four separate studies published in 2009 agreed that the RMB continued to be undervalued against the dollar but varied widely in their estimates of the undervaluation from 12% (Reisen 2009) to 25% (Rodrick 2009), and 40% (Cline and Williamson 2009)..

In June of 2010, China's central bank (the People's Bank of China) announced a resumption of RMB reforms (appreciation against the U.S. dollar). RMB/U.S. dollar exchange rate has generally declined since 2010 but at a rate that many have considered too slow to eliminate the undervaluation of the RMB against the dollar. Between June 2010 when appreciation of the RMB was resumed and July 2013, the RMB was allowed to appreciate by 10.7% with most of the appreciation occurring in 2010 and 2011 (Morrison and Labonte 2013). Nevertheless, undervaluation of the RMB persists. In May 2013, Cline (2013) estimated the undervaluation to be 6% while the IMF issued a range of estimates in 2012 ranging from 5% to 10% based on different analytical methodologies (IMF 2012).

Since the beginning of 2014, however, the Chinese Central Bank has reversed its policy of gradual, incremental appreciation of the RMB against the dollar, and has consistently intervened in currency markets to engineer a slide of the RMB against the dollar. Although the Chinese Central Bank has not fully explained this reversal of policy, some analysts see the move as punitive relative to speculators and an effort to prevent huge capital flows, or so-called hot money, from entering the country (see, for example, Gruber 2014).

The impact of the Chinese exchange rate policy on U.S. and world commodity markets depend on whether the respective commodities are exported or imported by China. In the case of soybeans, China has tended to be an importing country so that China's exchange rate policy has likely acted as a trade restriction. Nevertheless, when China acceded to the WTO in December 2001, soybean imports soared and have continued to increase at a rapid rate despite the RMB undervaluation (Figure 1). The rapid growth in the Chinese demand for livestock products over the years as China has opened its markets has challenged the ability of the Chinese agricultural sector to expand foodgrain production while, at the same time, diverting land into the production of feedgrains and oilseeds to support the continued expansion of its livestock industry. Together with price support and subsidy policies that have enhanced the relative profitability of foodgrains over oilseeds, the opening of Chinese markets to trade helped spur the meteoric rise in soybean imports for processing to keep up with the growth in demand for soymeal as a protein supplement in livestock feeds and to supply the growing domestic demand for cooking oil.

Figure 1: China Soybean Production, Crush, and Imports, 1965/66-2010/11



In principle, for any given commodity exported or imported by China, the effects of the RMB undervaluation are straightforward. The undervaluation boosts Chinese exports and restricts imports. For commodities like soybeans with lengthy vertical supply chains and joint product relationships, however, the effects of the RMB appreciation on Chinese and world soybean markets are more complicated to analyze because a change in the RMB/dollar exchange rate affects trade and prices of soybeans and soybean products simultaneously. For example, an appreciation of the RMB directly affects both the raw commodity market (soybeans) and the joint product markets (soybean meal and soybean oil) by restricting imports and raising prices in all markets. The soybean import restriction reduces soybean processing and, therefore, domestic supplies of soybean meal and oil, adding to the effects of the exchange rate undervaluation in those markets. At the same time, the import restrictions and higher prices in the product markets signals greater profitability from soybean processing, sending conflicting signals to soybean crushers from the higher soybean price signal from the restricted soybean imports. The net effects are not easily deduced and ambiguous in many ways.

Thus, when an RMB appreciation impacts a commodity in a vertical supply chain like soybeans, the actual effects will be more complicated and indeterminate. This paper, taking the soybean industry as a case, attempts to explain the impact of RMB appreciation on agricultural commodities with vertical supply chain using soybeans as an example.

2. Literature Review

A large number of studies have been done on the impacts of exchange rate uncertainty on trade, for example, Chambers and Just (1981) examined the impacts of exchange rate changes on U.S. agriculture. Although their results show that U.S. exports and agricultural prices are sensitive to exchange rate movements, the studies are dated and focus primarily on the effects of U.S. dollar exchange rates on U.S. agriculture. Cho, Sheldon, and McCorriston (2002) used a gravity model to examine the effects of exchange rate movements on bilateral trade patterns. The model focuses primarily on the general relationship among exchange rate, macroeconomic indicators, and international trade patterns. Their empirical analysis is based on aggregate data and ignores the impacts that exchange rate movements have across sectors of an economy. Mathew, Terry, and Agapi (2008) used a vector auto-regression (VAR) model to examine the impacts of exchange rate changes on foreign income and U.S. agricultural exports across 12 commodity subcategories including soybeans. Their analysis also ignores the potential complications of the joint product characteristics of soybean markets.

These studies used various empirical methods to examine the possible effects of exchange rate movements on trade and most come to same conclusion: commodity price and trade flows, especially in agricultural markets, are sensitive to the movements of exchange rate.

When the People's Bank of China (China's central bank) announced the move to a managed float exchange rate system in 2005, a number of studies analyzing various aspects of the effects emerged. For example, Willem (2006), Whalley and Wang (2011) used various methods to examine the impacts of a RMB appreciation on the trade surplus between China and U.S. in general, the studies conclude that a RMB appreciation would mitigate the U.S. trade deficit with China. Other studies, like Zhang (2012), used a multi-country (MC) macro-econometric Fair model to analyze the response of bilateral trade to a RMB appreciation and concludes that the appreciation would increase or have no effect on the trade surplus between China and U.S., a suspect conclusion. However, all studies of changes in the RMB have tended to focus on the effects of a RMB appreciation on aggregate trade patterns and have ignored the possible effects at the industry level.

Some studies have considered the impacts of a RMB appreciation on bilateral trade between China and other countries. For example, Chen (2011) used a GARCH model to evaluate the effects of a RMB appreciation against the Japanese yen on agricultural trade between the two countries. Izotov (2012) used a simple regression model to examine the impacts of a RMB appreciation on trade between China and Russia across 18 major commodities. These took a more industry approach to the trade effects of a RMB appreciation, but the product level effects were ignored.

As Anderson and Garcia (1989) pointed out: "The effects of exchange rate risk differ across countries and seem more measurable for specific commodities than for aggregate trade." Mutuc, Pan, and Hudson (2011) verified this conclusion when they use vector error-correction model to examine the transmission of price and exchange rate movements from China to the United States. Their anlaysis focuses at the product level and concludes that a shock to the exchange rate creates a positive shorter-run impact on corn, soybean, and cotton prices. Their analysis, however, did not consider any supply response or supply chain effects from the simulated RMB appreciation.

A number of other studies have examined the impacts of exchange rate changes on agricultural product trade, including Anderson and Garcia (1989) for soybean, Babula, Ruppel, and Bessler (1995) for corn, Molina, Mohanty, Pede, and Valera (2013) on rice. However, no study has focused on the effects of RMB undervaluation for a supply chain like soybeans and soybean products. Consequently, this paper intends to examine the potential impacts of the undervaluation of an exchange rate by a developing country, China specifically, on the market for a specific agricultural product, soybeans in this case, with a complex supply chain.

3. Conceptual Model

Given the lengthy vertical supply chain of soybeans, the effects of the RMB undervaluation on soybean, soybean meal, and soybean oil markets are first analyzed separately in this section.

Figure 2: Impacts of RMB Undervaluation on Soybean Market and Indirect Effects on Soymeal Market

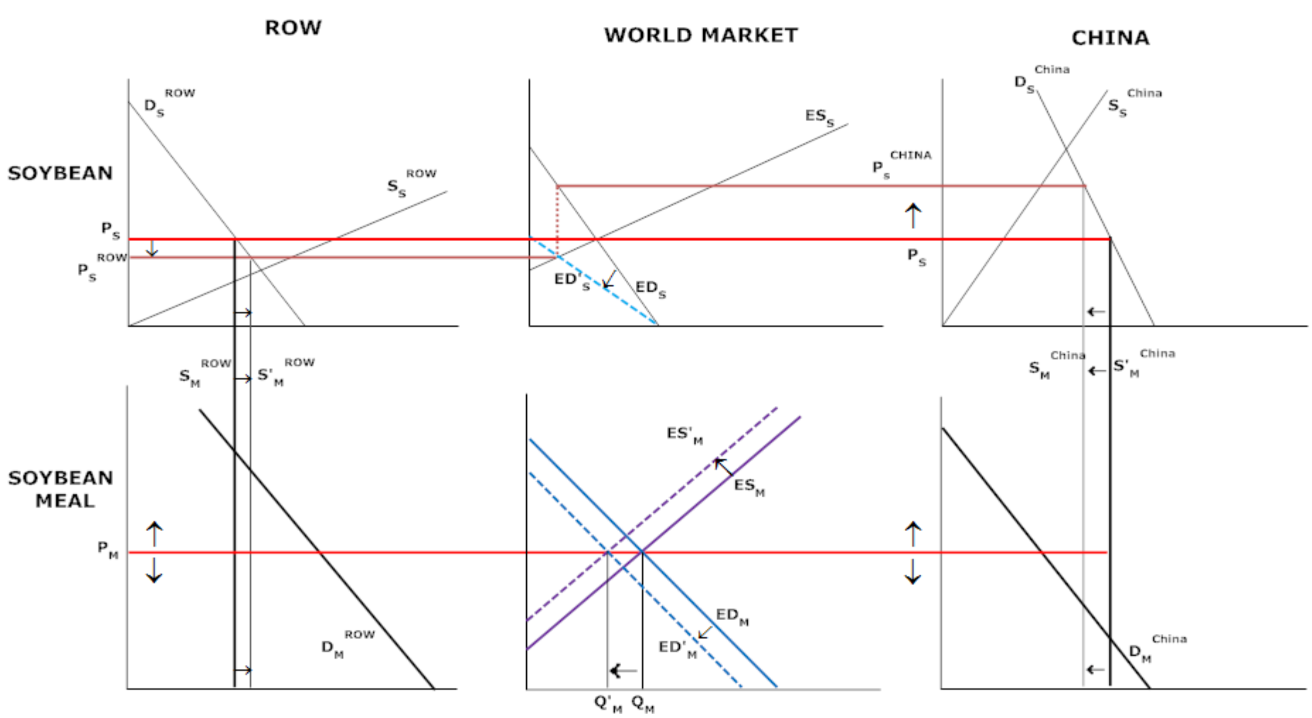
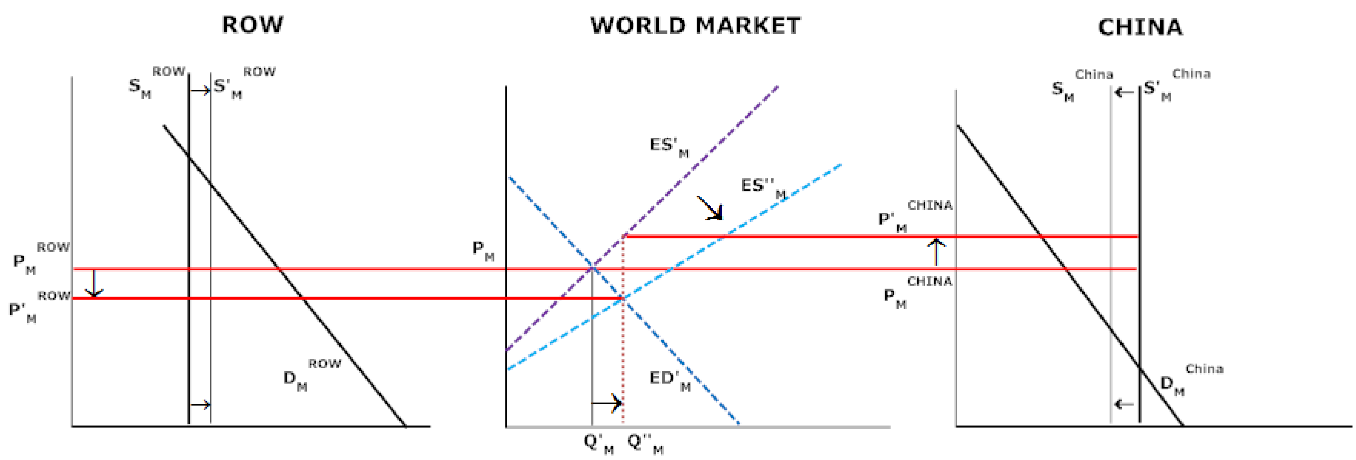


Figure 2 graphically represents world soybean and soymeal markets. China is appropriately illustrated as a soybean importing country with the Rest-of-the-World (ROW) as the net world soybean exporting region. World soybean equilibrium price (P_s^{US}) is determined at the intersection of the ROW excess supply of soybeans curve (ES_s) and China's excess demand for soybeans curve (ED_s). In this case the price linkage between China and the ROW is given as $P^{CHINA} = e_{US}^{CHINA} \bullet P_s^{ROW}$ where e_{US}^{CHINA} is the equilibrium RMB/$US exchange rate. To the ROW, when the RMB is undervalued against the US dollar, the undervaluation is perceived as a leftward rotation of China's excess demand curve (from ED_s to ED_s' in Figure 2) as Chinese demand wanes with the undervaluation. As a result, the ROW soybean price drops to P'^{ROW}_s, and the soybean price in China increases to $P's^{CHINA}$. The consequence of the RMB undervaluation, therefore, is lower exports of soybeans from ROW (and, thus, lower imports of soybeans by China), a higher price of soybeans in China, and a lower price in the ROW.

Because soymeal and soyoil are the joint products of the soybean crushing industries in both regions, the effects of RMB undervaluation on the soybean market have consequences for soymeal markets. The increase in the volume of soybeans crushed in the ROW and the decrease in volume crushed in China as a result of the RMB undervaluation leads to an increase in soymeal production in the ROW and a decline in production in China. As shown in Figure 2, China is shown as a soymeal net exporting country while the ROW is shown as a net soymeal importing region. Ignoring for now the direct effects of the RMB undervaluation on soybean meal markets, the changes in soymeal production in the two regions as a result of the RMB undervaluation effects on the soybean market lead to leftward shifts of both the ROW's ED for soymeal curve (ED_M to ED'_M) and China's ES for soymeal curve (ES_M to ES'_M). The result is an unambiguous decline in soymeal trade (from Q_M to Q'_M) but either an increase or a decrease in world soymeal price depending on elasticities and the relative sizes of the shifts of China's ES_M curve and the ROW's ED_M curve.

These changes, however, are not the final effects of the undervaluation of the RMB since the direct effects of the undervaluation on soybean meal markets were ignored. When the RMB is under-

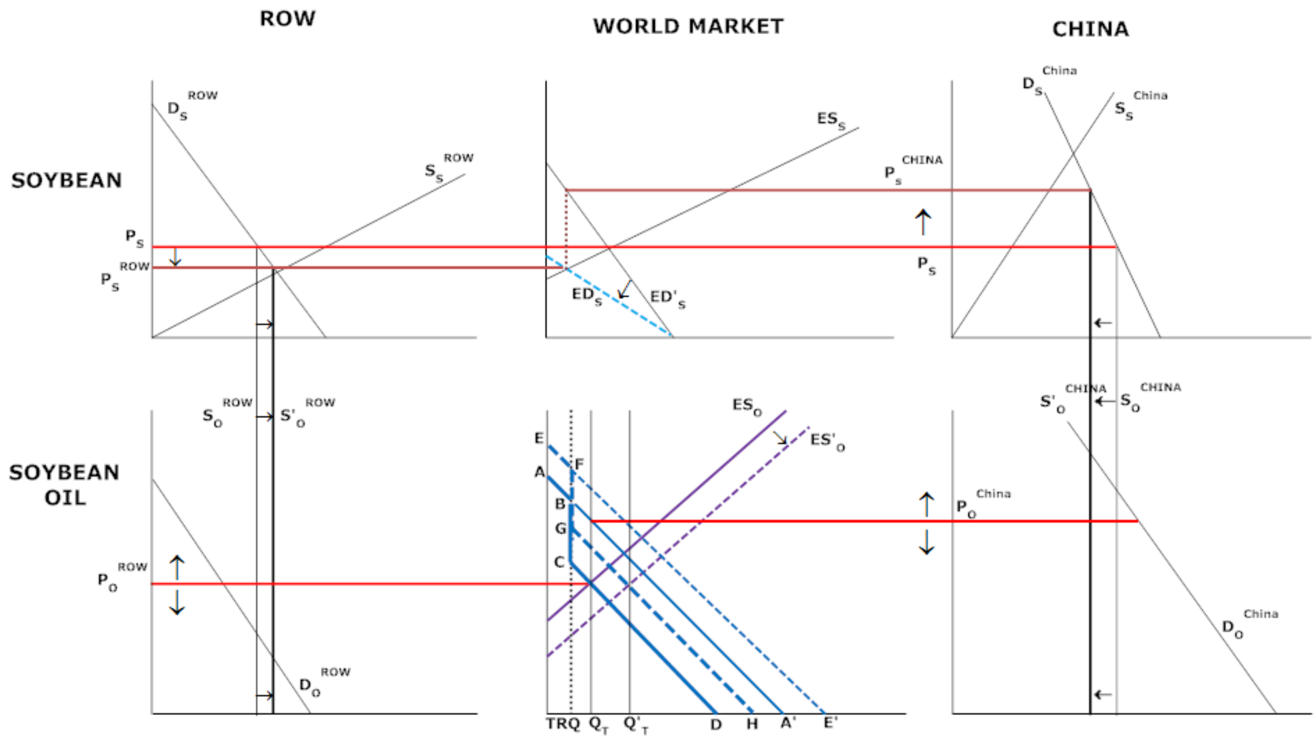
Figure 3: Impacts of RMB Undervaluation on Soybean Meal Market



-valued against the \$US, China's soymeal excess supply curve rightward rotates from ES'_M to ES''_M in Figure 3. As a result, ceteris paribus, soybean meal trade increases, the ROW soymeal price drops, and the soymeal price in China increases. The direct effects of the undervaluation of the RMB, therefore, are higher imports of soymeal from ROW (and, thus, higher exports of soymeal by China) along with a potentially higher price of soymeal in China (from $P'_M{}^{CHINA}$ to $P''_M{}^{CHINA}$), and a lower price in the ROW (from $P'_M{}^{ROW}$ to $P''_M{}^{ROW}$). Combined with the indirect effects of the RMB undervaluation through the soybean markets, the consequence is an ambiguous effect on soymeal trade and prices, depending on elasticities and magnitudes of ES and ED shifts.

The direct and indirect effects of the RMB undervaluation on the soyoil market are similar in nature to those discussed for soymeal with some exceptions. First, China tends to import soyoil rather than export it as is the case for soymeal. Second, China imposed different import polices for soyoil before and after 2006. Before 2006, as shown in Figure 4, China imposed a tariff-rate quota (TRQ) on its soyoil imports. With a TRQ in place, the excess demand curve AB is unaffected when imports are lower than the TRQ level (in-quota imports). At the point (B) that excess demand intersects the TRQ level, the demand function is kinked by the out-of-quota tariff on any imports above this point, which kinks the excess demand curve from AA' to ABCD. In the presence of a TRQ, the intersection of the excess supply curve ES_O and the inked excess demand curve ABCD determines the quantity of soyoil

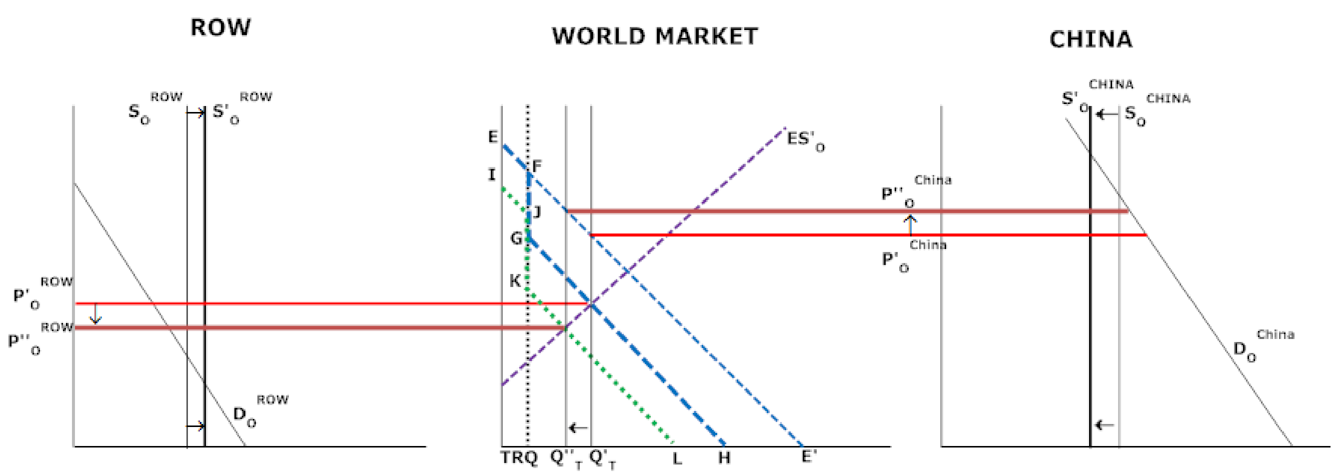
Figure 4: Impacts of Soybean Market on Soybean Oil Market (With TRQ)



traded (Q_T) and the price in ROW (P_O^{ROW}) and in China (P_O^{CHINA}) at the intersection of quantity supplied to the world market (Q_T in Figure 4) and the original excess demand curve of China (AA').

Ignoring for now the direct effects of the RMB undervaluation on soybean oil markets, the indirect effects of the RMB undervaluation from soybean markets on soyoil market is an increase in soyoil trade (from Q_T to Q'_T) but either an increased or a decreased soyoil prices in China and ROW depending on elasticities and the amount of out-quota tariff.

Figure 5: Impacts of RMB Undervaluation on Soybean Oil Market (With TRQ)



Note that the direct effects of the undervaluation on soyoil markets were ignored in the previous analysis. When the RMB is undervalued against the $US, China's excess demand curve leftward shifts from EFGH to IJKL(in Figure 5) as Chinese demand wanes with the undervaluation. As a result, soyoil trade drops from Q'_T to Q''_T (in Figure 5), the ROW soyoil price drops from $P'_O{}^{ROW}$ to $P''_O{}^{ROW}$, and the soyoil price in China increases from $P's^{CHINA}$ to $P''s^{CHINA}$ (in Figure 5).

In 2006, China eliminated the TRQ on its soyoil imports, which made China's soyoil market became a free trade market. No matter before or after 2006, combined the direct with the indirect effects of the RMB undervaluation through the soyoil markets, the consequence is an ambiguous effect on soyoil trade and a potentially higher soyoil price in China and lower price in the U.S., depending on elasticities and magnitudes of excess supply curve and excess demand shifts.

Furthermore, any RMB-undervaluation-led change in soymeal or soyoil price also has indirect effects on the soybean industry. For example, the higher soymeal or soyoil price drives higher soybean demand which puts upward pressure on the soybean price. The direct and indirect effects of the RMB undervaluation from soybean markets to soymeal markets and vice versa lead to offsetting effects on the prices and trade. The final result depends critically on the price elasticities of supply and demand for soybeans, soymeal and soyoil in all countries.

In summary, determining the effects of the RMB undervaluation on world soybean, soymeal, and soyoil markets and prices is complicated by both the direct effects of the undervaluation on each market as well as the indirect, cross market effects up and down the supply chain. Changes in soybean prices caused by the RMB undervaluation have effects on down-stream industries. Inversely, changes in prices in the down-stream industries (soymeal and soyoil markets) impact the upstream industry (soybeans) and, therefore, each other. Because the joint effects of the RMB undervaluation given the joint product characteristics of soybean markets are largely intractable graphically and depend critically on the elasticities of supply and demand across all world soybean and soybean product markets as well as the extent of the exchange rate pass-through in each market, an empirical investigation is required.

4. Methodology and Data

The analysis of the RMB undervaluation on soybean and products markets in this paper utilizes SOYMOD, a 192-equation, annual econometric, non-spatial, price equilibrium simulation model of world soybean and soybean product markets (see Williams 1981; Williams and Thompson 1984; Williams 1985; Williams 1994; Williams 1999; Williams, Shumway, and Love 2002; and Williams, Capps, and Bessler 2009 for more details on the model). SOYMOD allows for the simultaneous determination of the supplies, demands, prices, and trade of soybeans, soymeal, and soyoil in seven major world trading regions: (1) the United States, (2) China, (3) Argentina, (4) Brazil, (5) the European Union, (6) Japan, and (7) a Rest-of-the-World region which accounts for the effects of other new growth areas in world soybean markets. The domestic market of each region in the model is divided into four simultaneous blocks of equations: (1) a soybean block, (2) a soybean meal block, (3) a soybean oil block, and (4) an excess supply or excess demand block.

For each region, the first three blocks contain behavioral relationships specifying the manner in which soybean supply (acreage planted, acreage harvested, soybean yields, and production), soybean domestic demand (crush and stocks), and the supply, consumption, and stocks of soybean meal and soybean oil behave in response to changes in variables like prices of soybeans and products, prices of various competing commodities, technology, income, livestock production and prices, government policy, etc. as appropriate.

For the U.S., the soybean block contains regional rather than national acreage planted, acreage harvested, yield, and production equations (equation (1) in Figure 6) for seven production regions (Atlantic, Cornbelt, Delta, Lakes, Plains, South, and Other) to represent the soybean supply relationship and account for interregional competition within the United States:

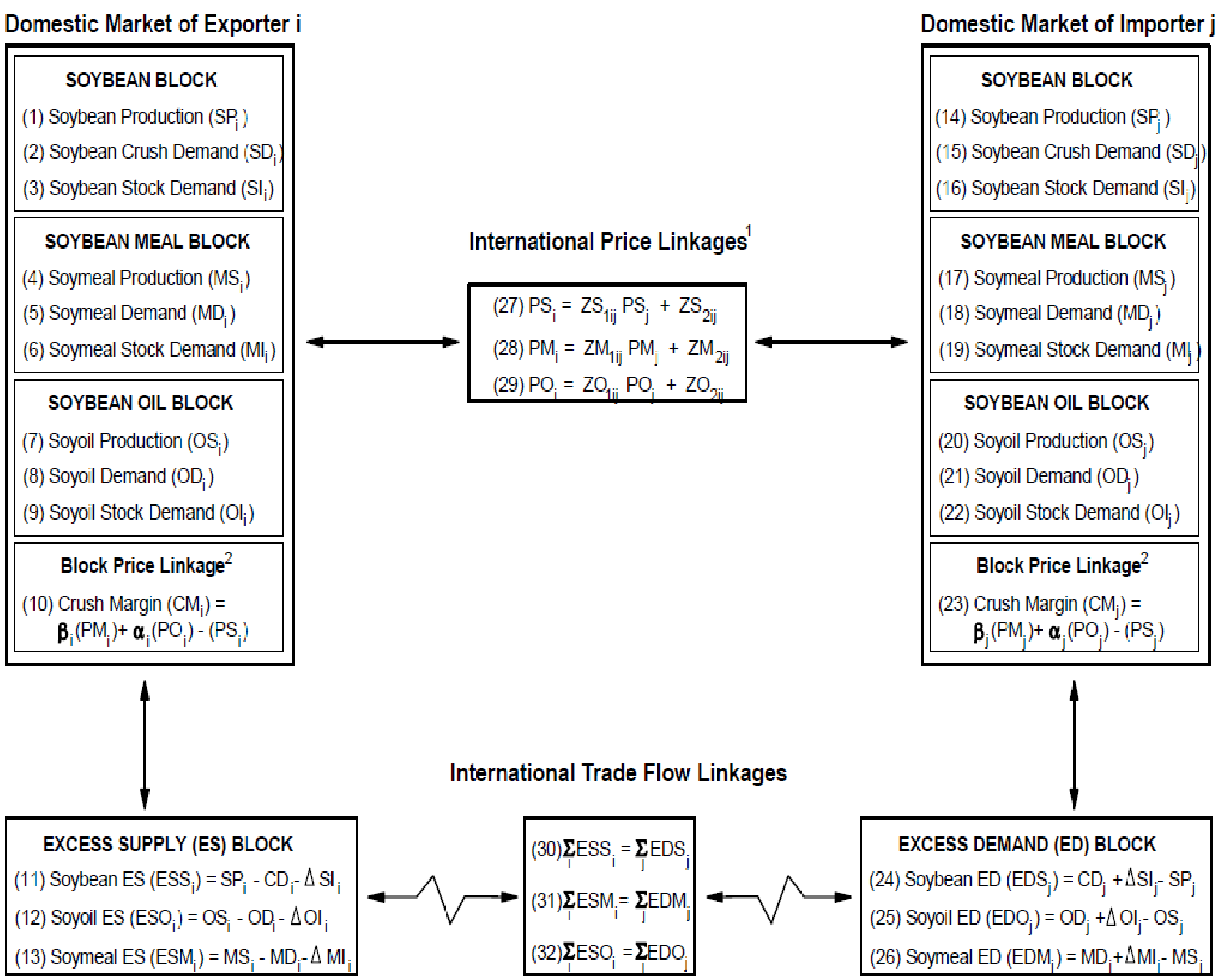
[1] $AS_{kt} = AS_{kt}(PS^e, \alpha_{kt})$, *[2]* $HS_{kt} = HS_{kt}(AS_{kt})$, *[3]* $SS_{kt} = YS_{kt} \quad HS_{kt}$,

where k = production region 1,..., 7; t = time period; AS = soybean acreage planted; HS = soybean acreage harvested; YS= soybean yield (exogenous); SS = soybean production; RS = soybean research stock variable; α and θ are appropriate exogenous shift variables, and PS^e = expected soybean farm price for each region and is defined as:

[4] $PS^e = MAX(PS_{t-1}, LS_t) \bullet D5901 + MAX(PS_{t-1}, 0.85 \bullet TS_t + 0.15 \bullet MAX(PS_{t-1}, LS_t)) \bullet D0212$

where LS = the soybean loan rate; TS = soybean target price; D5901 = indicator variable which equals 1 for 1959/60 through 2001/02 and 0 otherwise; and D0212 = indicator variable which equals 1 for 2002/03 through 2012/13 and 0 otherwise.

Figure 6. Structure of SOYMOD



Note: i = any exporter i=1, ... , n; and j = any importer j=1, ... , k. Also, Δ should be read "change in."

[1] The Z_1 and Z_2 include all multiplicative (e.g. exchange rates and *ad valorem* subsidies) and additive (transportation costs, specific tariffs, etc.) measures that come between prices of country i and j.

[2] β and α are meal and oil extraction rates; PS, PO, and PM are soybean, soyoil, soymeal prices.

The general specification of the domestic demands (D) in the soybean, soybean meal, and soybean oil blocks of SOYMOD (corresponding to equations (2), (5), and (8) for any exporting region i and equations (15), (18), and (21) for any importing region j in Figure 13) is: *[8]* $D_{ist} = D_{ist}(P_{ist}, ß_{st})$, where i = world region {1, ... , 6}; s = commodity {soybeans, soybean meal, and soybean oil}; t = time period; P = domestic market price; and β represents appropriate shift variables.

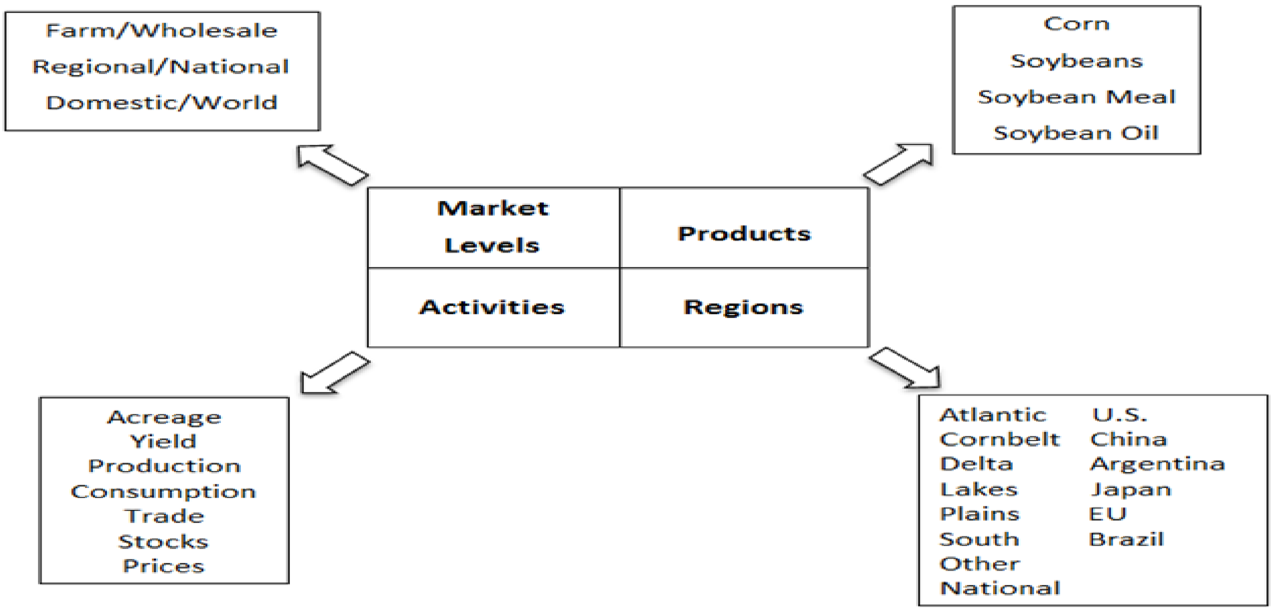
Simultaneous interaction of soybean and product markets within each region in SOYMOD is insured through the endogenous soybean crush margin (equations (10) and (23) in Figure 6) which is the own price variable in the crush demand equations ((2) and (15) in Figure 6). The fourth block in each domestic market (equations (11)-(13) and (24)-(26) in Figure 6) includes net excess supply relationships for exporting regions and net excess demand relationships for importing regions specified as the residual differences between their respective domestic supply and demand.

Because of the important simultaneous interaction between the U.S. soybean and corn markets, SOYMOD also includes a model of the U.S. corn market. The specification of the U.S. supply and demand blocks of the corn model is similar to that for soybeans. The U.S. corn market model, however, is closed with a world corn import demand equation.

The soybean and soybean product markets of the trading countries in the model are linked through international price and trade flow relationships. The prices of soybeans, soymeal, and soyoil in exporting and importing regions are linked through price transmission equations (equations (27)-(29) in Figure 6) following Bredahl, Meyers, and Collins (1979) which account for the effects of exchange rates as well as tariffs, export subsidies, border taxes, transportation costs, etc. and other factors (the Zij) that drive a wedge between prices in each world region. International market clearing conditions (equations (30)-(32) in Figure 6) require equality of the world excess supply and demand for soybeans, soymeal, and soyoil in each time period.

Figure 7 summarizes the dimensions of SOYMOD. The model includes acreage, yield, production, consumption, inventory, price, and trade relationships and operates at both the farm and wholesale levels in all countries/regions for corn, soybeans, soymeal, and soyoil. The U.S. model includes seven production regions and the full model includes seven trading countries/regions.

Figure 7. Dimensions of SOYMOD



Because SOYMOD includes 192 endogenous variables and 501 exogenous variables, a large amount of data is required to support the econometric estimation of the model parameters and the simulation of the model for analytical purposes. Two types of data are needed for the analysis of the effects of the RMB undervaluation on world soybean and product markets: (1) data to support SOYMOD (e.g., supply, demand, trade, price, policy, etc. data by country and commodity over time) and (2) the RMB/$US exchange rate over time.

The first set of data relates to most of the endogenous and exogenous variables in the model (supply, demand, trade, price, policy, etc. by country and commodity over time) and were taken from numerous public sources. For the U.S., much of the data was available from various USDA sources (such as USDA-ERS, USDA-FAS, and USDA-NASS) for 1959/60 through 2012/13. USDA sources provided much of the supply and demand data for other countries as well. Price data for other countries came from various country-specific sources. International macroeconomic data (such as incomes, inflation rates, etc.) were taken primarily from the International Financial Statistics (IFS) of the International Monetary Fund (IMF) and numerous country specific sources.

For the second set of data, the actual (undervalued) RMB/$US exchange rate for each year over the 1994 to 2013 period was taken from IFS (IMF 2014). For the simulation analysis, data for the equilibrium RMB/$US in each year were necessary. There are numerous methods to determine an equilibrium exchange rate and the results are vastly different for different methods. Most analyses to determine the equilibrium exchange rate use one of the following approaches:

1. The Fundamental Equilibrium Exchange Rate (FEER) method;
2. The Purchasing Power Parity (PPP) method; or
3. The Behavioral Equilibrium Exchange Rate (BEER) method.

Morrison and Labonte (2013) point out that "most studies of the RMB's projected market value against the dollar have involved one-time estimates made for a given period of time and thus may not reflect fundamental economic changes that may have subsequently occurred, which in turn would affect estimates of the RMB's equilibrium exchange rate with the dollar in other years." This made the work of Williamson and Cline (2008-2013) the most reliable source for estimates of the equilibrium RMB/$US exchange rate. They provide a continuous estimation of the equilibrium exchange rates for a number of countries including China using the FEER method.

However, because Williamson and Cline calculate the equilibrium RMB exchange rate beginning in 2008, estimates of that equilibrium rate between 1994 and 2007 from other sources had to be used for the simulation analysis. Considering that no consistent estimate of that exchange rate from a single source exists before 2008, the mean value of estimates in each year from various sources based on different methods was taken as the equilibrium RMB exchange rate for purposes of the simulation analysis in the 1993/94-2007/08 period.

Table 1 is the RMB/$US exchange rates used in the simulation. The actual RMB/$US represents the historical data of RMB exchange rate from 1993/94 to 2012/13, while the equilibrium RMB/$US represents the RMB exchange rate at the equilibrium level. The RMB exchange rates at the equilibrium level are estimates from various sources based on different methods, as described earlier. The data

Table 1. RMB Exchange Rate Data from 1993/94 to 2012/13

Market Year	Actual RMB/$US	Equilibrium RMB/$US	Percentage of Undervaluation	Source
1993/94	8.6	6.2	38.7	Chang and Shao (2004) Chang (2007)
1994/95	8.4	6.6	27.3	
1995/96	8.3	6.9	20.3	
1996/97	8.3	7.0	18.6	
1997/98	8.3	6.8	22.1	
1998/99	8.3	6.5	27.7	
1999/00	8.3	5.8	43.1	Jeong and Mazier (2003), Frankel(2006), Chang, Shao (2004), Chang (2007)
2000/01	8.3	6.3	31.7	Chang and Shao (2004) Bénassy-Quéré et al (2004)
2001/02	8.3	6.0	38.3	Chang, Shao (2004) Coudert and Couharde (2005)
2002/03	8.3	6.1	36.1	Chang & Shao (2004) Bénassy-Quéré et al (2004) Coudert and Couharde (2005)
2003/04	8.3	6.3	31.7	Bénassy-Quéré et al (2004)
2004/05	8.2	5.7	43.9	Cline (2005)
2005/06	8.0	6.6	21.2	Anderson (2006)
2006/07	7.6	5.6	35.7	Cline and Williamson (2008)
2007/08	6.9	5.3	30.2	Cline and Williamson (2008)
2008/09	6.8	4.9	38.8	Cline and Williamson (2009)
2009/10	6.8	5.6	21.4	Cline and Williamson (2010)
2010/11	6.5	5.1	27.5	Cline and Williamson (2011)
2011/12	6.3	5.9	6.8	Cline and Williamson (2012)
2012/13	6.2	5.8	6.9	Williamson (2013)

shows significant undervaluation for RMB exchange rate against U.S. dollar through the whole period between 1993/94 and 2012/13. Note that after 2006/07, when China reformed its exchange rate regime, RMB exchange rate was less undervalued.

To examine the effects of RMB undervaluation on global soybean and soybean products markets, two scenarios were analyzed over the 1993/94-2012/13 period using SOYMOD:

1) With an undervalued RMB and

2) With the RMB exchange rate set at the estimated equilibrium level.

The first scenario represents the actual situation, which includes the actual effects on the markets from the RMB/$US undervaluation and vertical supply chain relationship. The simulation was conducted based on the historical situation of SOYMOD, which approximately replicated the historical value from year 1993/94 to 2012/13. Given that Chinese soybean and products markets were not open to trade until 1993/94, the simulation analysis begins with the liberalization of those markets.

The second scenario analysis was conducted by replacing the actual RMB/$US exchange rate in SOYMOD with the estimated equilibrium level as discussed then simulating the model again to generate a new set of variable values for the global soybean and products markets from 1993/94 to 2012/13. In this scenario, because the RMB exchange rate is the only variable that has been changed in SOYMOD, the simulation results represent the market situation that would have occurred over time if the RMB exchange rate had been at the equilibrium level. Differences in the model variable values (world supply, trade, etc.) between the two scenarios are taken as the direct measures of the effects of the RMB undervaluation on global soybean and products markets.

5. Simulation Results

This section provides the results of simulating the effects of the RMB undervaluation on soybean and products markets in China, United States and the rest of world. The discussion reflects the effects that the undervalued RMB/$US exchange rate has had on those markets over time.

Effects of the RMB Undervaluation on Chinese Soybean and Soybean Product Markets

Comparing the results of two simulation scenarios, the simulated differences in the historical level (scenario 1) of the model variables from those with RMB/$US exchange rate at the equilibrium level (scenario 2) indicate that the burden of the world soybean and products markets adjustments to the RMB undervaluation were borne by China.

Table 2: RMB undervaluation effects on China Soybean and Products Prices

Average Price Change In:	**1993/94 – 2004/05**		**2005/06 – 2012/13**		**1993/94 – 2013/14**	
	Yuan/MT	%	Yuan/MT	%	Yuan/MT	%
Soybean Import	451.5	31.0	495.1	18.0	468.9	23.7
Soybean Producer	528.9	27.6	580.0	17.5	549.3	22.2
Soymeal	484.8	24.0	575.7	19.3	521.2	21.6
Soyoil	1421.9	23.8	1899.7	25.1	1613.0	24.4

Effects of the RMB Undervaluation on Chinese Soybean, Soymeal, and Soyoil Prices

The simulation results indicate that the import and producer prices of soybeans in China were 23.7% and 22.2% higher on average, respectively, between 1993/94 and 2012/13 as a result of the RMB undervaluation than would have been the case if the RMB had been at its equilibrium value (Table 2). Considering the RMB undervaluation just drove U.S. soybean price dropped by 3.2% on average, the divergence between the magnitudes of price changes in China and U.S. is caused by the different elasticities of domestic supply and demand in both countries (China is with more elastic demand than U.S.), which also indicates that China actually has borne most of the burden from its own exchange rate undervaluation policy over the years. The higher domestic soybean price drove higher soybean planting acreage in China and, consequently, increased the domestic production of soybeans in China by 19.6% on average (Table 3). The results also show that the prices of soymeal and soyoil in China were also 21.6% and 24.4% higher, respectively, than they would have been with an equilibrium RMB/$US exchange rate (Table 2).

Effects of the RMB Undervaluation on Chinese Domestic Markets and Trade

Chinese soybean demand was also lower as a result of the RMB undervaluation than Chinese soymeal and soyoil demand from 1994/95 to 2004/05 implying a larger decrease in soymeal and soyoil supplies than in their respective demands during that period which boosted Chinese soymeal and soyoil prices upward (Figure 8). In 2004/05, China announced its intention to reform its exchange rate regime and move toward a managed float of the RMB based on market supply and demand with reference to a basket of currencies. China started a period of sizable appreciation of the RMB exchange rate. After 2004/05, although China halted the RMB appreciation for a while due to the credit crisis in 2007/08, the overall relative decrease in soybean crush demand on average was still larger than the decrease in soymeal and soyoil demand, which motivated a downward trend in the soymeal and soyoil prices in China after 2004/05. Thus, the net effects of the RMB undervaluation on soymeal and soyoil prices over the full period between 1993/94 and 2012/13 were positive (Table 2).

Table 3: RMB Undervaluation Effects on World Soybean and Products Markets, 1993/94-2012/13

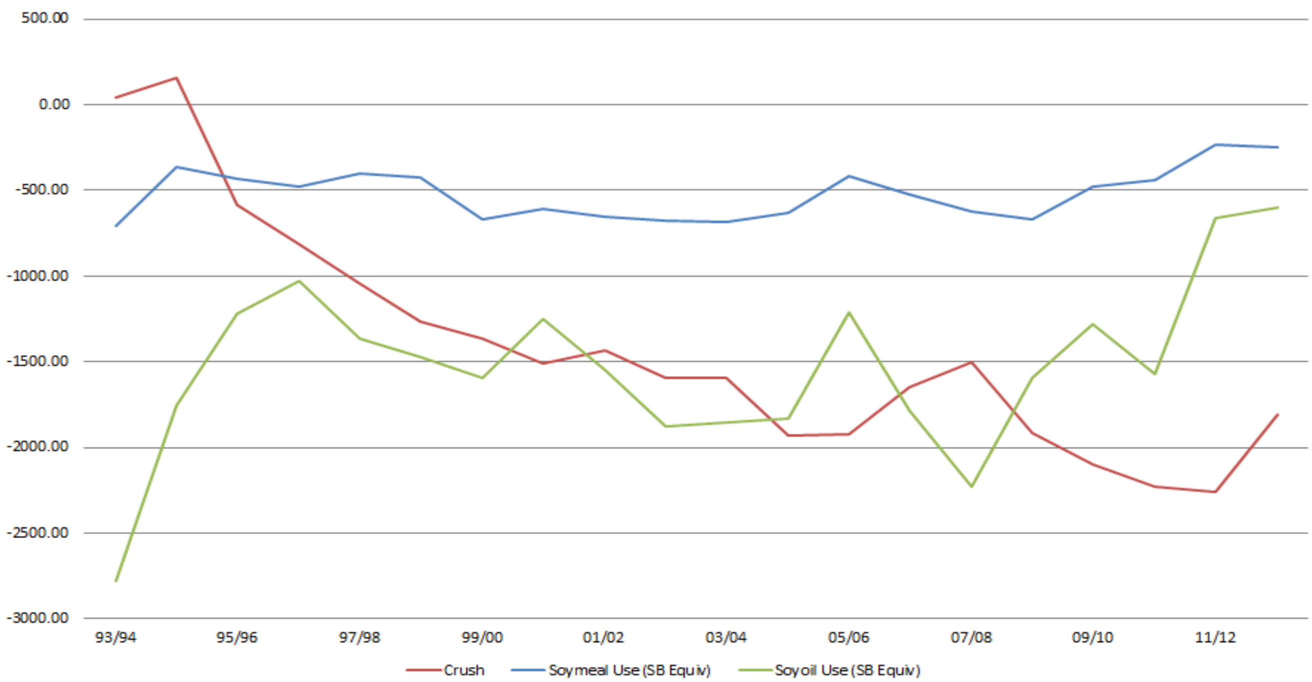
Average Change In	1993/94 – 2004/05		2005/06 – 2012/13		1993/94 – 2012/13	
	1,000 MT	%	1,000 MT	%	1,000 MT	%
Production						
United States	-932.3	-1.3	-1840.9	-2.1	-1314.8	-1.6
Argentina	-589.4	-2.1	-1150.3	-2.5	-825.6	-2.3
Brazil	-1536.9	-3.6	-2485.8	-3.7	-1936.4	-3.6
China	1981.3	15.1	3022.7	25.9	2419.8	19.6
Total	-1077.2		-2454.3		-1657.0	
Crush						
United States	-108.1	-0.3	-332.6	-0.7	-197.9	-0.4
Argentina	-181.8	-0.9	-363.2	-1.1	-254.4	-1.0
Brazil	-258.6	-1.1	-715.3	-2.1	-441.3	-1.6
China	-1078.6	-6.2	-1921.9	-4.0	-1415.9	-5.3
EU	295.2	2.0	618.3	5.1	424.5	3.2
Japan	7.1	0.2	11.9	0.5	9.0	0.3
Total	-1324.7		-2702.7		-1876.0	
Soymeal use (SB Equiv)						
United States	-43.8	-0.1	-126.8	-0.4	-77.0	-0.2
Argentina	-0.7	-0.1	-2.0	-0.2	-1.2	-0.2
Brazil	-11.8	-0.1	-21.9	-0.1	-15.8	-0.1
China	-561.3	-3.9	-453.8	-1.1	-518.3	-2.8
EU	-18.4	-0.1	-61.6	-0.2	-35.7	-0.1
Japan	-23.8	-0.5	-77.7	-1.5	-45.4	-0.1
Total	-659.7		-743.9		-693.4	
Soyoil use (SB Equiv)						
United States	77.2	0.2	-96.0	-0.2	7.9	0
Argentina	2.3	0.3	-5.7	-0.1	-0.9	0.1
Brazil	6.2	0.1	-7.9	0	0.6	0
China	-1631.8	-7.4	-1365.4	-2.5	-1525.3	-5.4
EU	9.6	0.1	-18.4	-0.1	-1.6	0
Japan	4.1	0.1	-9.7	-0.4	-1.4	-0.1
Total	-1532.4		-1503.1		-1520.7	

The simulation results also indicate that Chinese soybean imports were on average 13.9% lower than they would have been with an equilibrium exchange rate over the 1994/05 to 2012/13 period (Table 4). Chinese soymeal exports were 64.7% lower in each year on average as a result of RMB undervaluation from 2005/06 to 2012/13. Before 2005/06, China acted as a soymeal importer in most of time, that's the reason the results for average changes in China's soymeal exports during 1993/94 and 2004/05 in table 4 are not available. Chinese soyoil imports, however, were only slightly affected by the RMB exchange undervaluation (lower by only 0.8% annually).

Table 4: RMB Undervaluation Effects on World Soybean and Products Trade

Average Change In	1993/94 – 2004/05		2005/06 – 2012/13		1993/94 – 2013/14	
	1,000 MT	%	1,000 MT	%	1,000 MT	%
World Soybean Imports						
China	-2894.7	-25.0	-4944.5	-10.0	-3714.7	-13.9
EU	295.2	2.0	618.3	5.1	424.5	3.2
Japan	7.1	0.2	11.9	0.4	9.0	0.2
Rest of the World	325.8	3.0	317.2	2.6	322.4	2.7
Total	-2266.6		-3997.1		-2958.8	
World Soybean Exports						
United States	-758.0	-2.9	-1439.5	-4.0	-1030.6	-3.3
Argentina	-358.4	-6.7	-787.1	-8.0	-529.9	-7.5
Brazil	-1150.2	-9.3	-1770.5	-8.4	-1398.3	-8.9
Total	-2266.6		-3997.1		-2958.8	
World Soymeal Imports						
EU	-248.1	-1.4	-535.9	-2.5	-363.2	-1.8
Japan	-23.7	-5.6	-67.9	-5.1	-41.4	-5.2
Rest of the World	-525.2	-4.0	-1540.1	-6.0	-931.1	-4.9
Total	-796.9		-2143.9		-1335.7	
World Soymeal Exports						
United States	-50.9	-0.7	-162.8	-1.8	-95.7	-1.2
Argentina	-143.7	-1.1	-281.4	-1.1	-198.8	-1.1
Brazil	-192.5	-1.6	-537.4	-3.9	-330.5	-2.6
China	NA	NA	-1162.3	-64.7	NA	NA
Total	NA		-2143.9		NA	
World Soyoil Imports						
China	-85.1	-6.3	99.5	5.9	-11.2	-0.8
Japan	-0.6	-0.2	-4.2	-0.3	-2.0	-0.3
Rest of the World	18.3	0.4	-218.8	-3.8	-76.6	-1.5
Total	-67.4		-123.4		-89.8	
World Soyoil Exports						
United States	-33.9	-4.0	-35.8	-3.3	-34.6	-3.7
Argentina	-34.2	-1.1	-68.0	-1.4	-47.7	-1.3
Brazil	-50.5	-3.0	-135.8	-6.8	-84.6	-4.7
EU	51.2	7.8	116.1	27.3	77.2	34.6
Total	67.4		-123.4		-89.8	

Figure 8. Change in China Soybean and Products Use



The higher prices of soybeans, soymeal and soyoil put downward pressure on the domestic consumption of the two commodities in China. Consequently, soybean, soymeal, and soyoil use are lower on average each year between 1993/94 and 2012/13 by 5.3%, 2.8% and 5.4%, respectively, than would have been the case with an equilibrium exchange rate.

Effects of the RMB Undervaluation on U.S. Soybean and Product Markets

The simulation results indicate that the RMB undervaluation has had some negative effects on the price, production, consumption and exports of U.S. soybean and soybean products markets.

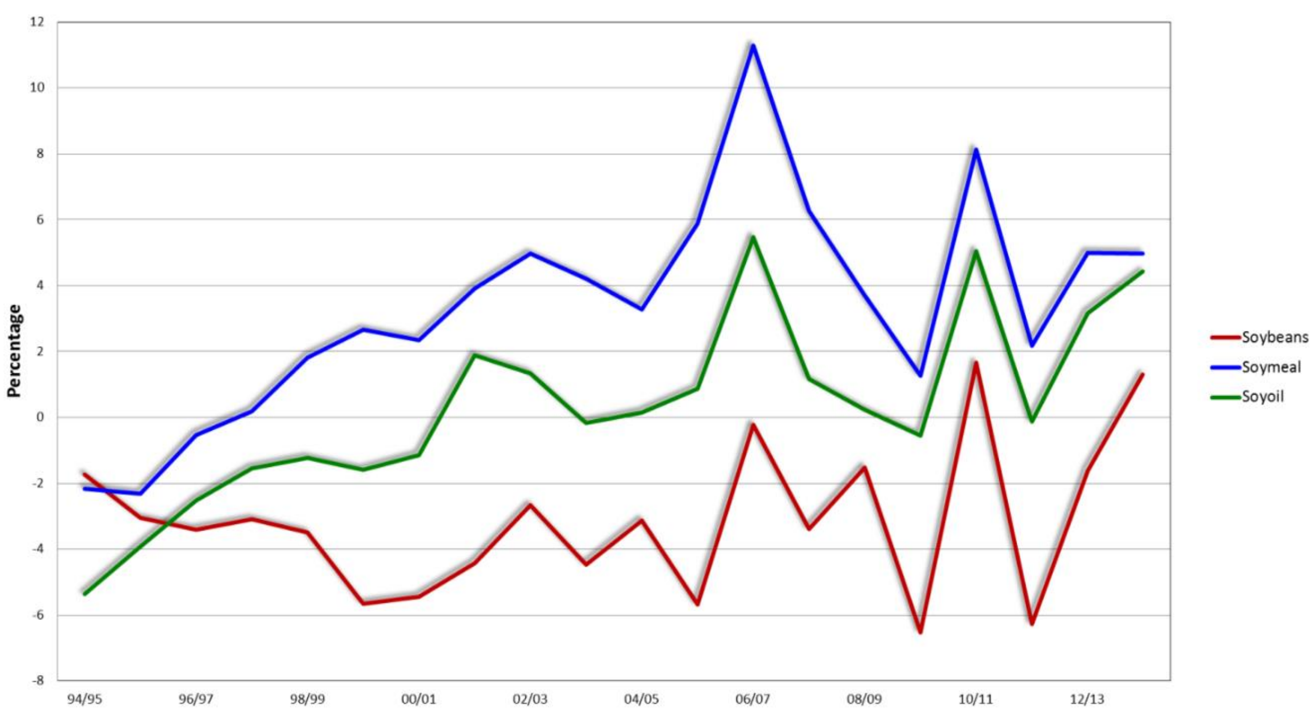
U.S. Soybean and Product Price Effects

The undervalued RMB/$US exchange rate affected U.S. soybean, soymeal and soyoil prices in United States significantly (Figure 9). The domestic soybean price was lower by 3.2% on average in each year as a result of the undervaluation. The undervalued RMB reduced China's purchasing power in U.S. soybeans, which drove lower imports of soybean by China (and, thus lower exports from U.S.), and further drove a lower price in U.S.. The simulation results also indicate that the soymeal and soyoil prices were higher on average in each year by 3.4% and 0.3%, respectively. For the higher soymeal price in U.S., it is possibly because that U.S. and China are both net exporters of soymeal, the undervalued RMB enhanced the purchasing power of importers, which combines with the effects of soybean market to motivate a higher price of soymeal in U.S. For soyoil price, although the overall average price is 0.3% higher than it would be, Table 5 shows different effects before and after 2006. Before 2006 (1993/94-2004/05), when China imposed TRQ on its soyoil imports, the average price of soyoil in U.S. was 1.1% lower than it would be. In contrast, after 2006, when China eliminated TRQ on the soyoil imports, the average price of soyoil was 2.4% higher than it would be. The divergence of price changes between these two periods (before and after 2006) is one indication of the trade distorting effects of the TRQ.

Table 5: RMB undervaluation effects on U.S. Soybean and Products Prices

Average Price Change In	1993/94 – 2004/05		2005/06 – 2012/13		1993/94 – 2012/13	
	$/bu	%	$/bu	%	$/bu	%
Soybean	-0.2	-3.9	-0.2	-2.1	-0.2	-3.2
	$/ton	%	$/ton	%	$/ton	%
Soymeal	3.5	2.0	14.7	5.3	8.0	3.4
	Cent/lb	%	Cent/lb	%	Cent/lb	%
Soyoil	-0.3	-1.1	0.8	2.4	0.2	0.3

Figure 9. Changes in Prices in U.S.



U.S. Domestic Consumption and Export Effects

The lower level of soybean production as a result of the RMB undervaluation reduced the availability of domestic U.S. soybean supplies for crushing despite the upward pressure on crush from a lower soybean price by about 0.4%. The undervalued RMB/$US exchange rate also resulted in a slightly lower annual average soymeal consumption of 0.2% while the effects on soyoil consumption are not significant. The relatively larger increase in soybean crush demand than in soymeal or soyoil demand resulted in a larger increase in soymeal and soyoil supplies than in their respective demands leading to lower prices of both soybean meal and oil.

Because the undervalued RMB exchange rate drove the level of U.S. soybean, soymeal and soyoil production lower, the U.S. soybean export volume was also lower. Based on the simulation results, average annual soybean exports over the 1993/94 to 2012/13 period were 3.3% lower than would have been the case with the RMB/$US exchange rate at its equilibrium level (Table 3). U.S. exports of soymeal and soyoil were 1.2% and 3.7% lower, respectively (Table 3).

Effects of the RMB Undervaluation on ROW Soybean and Soybean Product Markets

The simulation results indicate that soybean production in Argentina and Brazil was lower by 2.3% and 3.6%, respectively, on average over the period of analysis. Soybean consumption in those two countries was also somewhat lower by 1.0% and 1.6%, respectively, on average but higher by 3.2% and 0.3% on average in the EU and Japan, respectively. Soymeal consumption was lower in those four countries by between 0.1% and 0.2% over the period of analysis. Soyoil consumption changes in those countries were between -0.1% and 0.1% over the same period.

EU and Japanese soybean imports were higher as a result of the RMB undervaluation by 3.2% and 0.2%, respectively, in each year over the period of analysis. Over the same period, Argentina’s and Brazil’s annual soybean exports were lower by 7.5% and 8.9%, respectively, on average. The annual soymeal trade volume of those four countries/regions changed by between -1.1% and -5.2% over the period of analysis. The annual soyoil trade volume of those same countries changed by between -0.3%

and 34.6% over the same period. Details for the effects of RMB undervaluation on the rest of world can be found in table 3 and table 4.

6. Summary and Conclusions

This paper analyzed the impacts of China's exchange rate policy on the world soybean and soybean products markets. Distinct from previous studies, it focused on a commodity market with a lengthy vertical supply chain. By taking the soybean industry as a case, the analysis also considered the joint effects of the undervaluation of the RMB/$US exchange rate and the interactions along vertical supply chain relative to prices, supplies, demands, and trade of world soybean and soybean products. Using a price equilibrium simulation model of world soybean and soybean product markets, the effects of Chinese exchange rate policy on world commodity markets in the case of soybeans and soybean products was analyzed. In the simulation model, two scenarios were formulated to capture the effects of the RMB undervaluation on the soybean market. The first scenario represented the historical situation, which included all the actual effects on the markets from the RMB undervaluation given the supply chain and joint product relationships in world soybean and product markets. The second scenario analysis was conducted by replacing the actual RMB/$US exchange rate by an estimated equilibrium rate which represented the market situation that would have occurred if the RMB exchange rate had been at the equilibrium level. Considering there are numerous methods to determine an equilibrium exchange rate and the results are vastly different for different methods. Because no single source available before 2009, the mean value of estimates in each year from various sources based on different methods was taken as the equilibrium RMB exchange rate in the 1993/94-2007/08 period for decreasing the variability between different methods. For the period after 2007/08, Williamson and Cline's continuous estimation of the equilibrium exchange rates on a semi-annual basis using the FEER method were taken as the RMB exchange rate at equilibrium level.

The simulation results indicated that the RMB undervaluation had significant effects on the world soybean and soybean products markets from 1993/94 to 2012/13. Compared to the case in which the RMB was at its equilibrium value, the undervalued RMB was found to have had the following salient effects in world soybean markets over the 1993/94 to 2012/13 period of analysis:

- The consumption of soybean is redirected from China to EU and Japan.
- The production of soybean is redirected from United States, Argentina and Brazil to China.
- Higher average annual Chinese soybean import prices and soybean production by 23.7% and 19.6%, respectively;
- Lower average annual Chinese soybean imports by 13.9%;
- lower average annual U.S. soybean price of 3.2%;
- Lower average annual U.S. exports of soybean, soymeal, and soyoil averaged by 3.3%, 1.2%, and 3.7% in each year;
- Lower average annual soybean production in Argentina and Brazil by 2.3% and 3.6%, respectively;
- Higher average annual EU and Japanese soybean imports by 3.2% and 0.2%, respectively; and
- Lower average annual Argentine and Brazilian soybean exports by 7.5% and 8.9% respectively.

The reform of the Chinese exchange rate policy in 2004/05 has led to an appreciation in RMB/$US rate from the low levels of earlier years but remains undervalued according to most observers. The appreciation, however, has alleviated some of the distortion in world soybean and soybean product markets. Also, China's policy of eliminating the TRQ for soyoil in 2006 possibly counteracted the effects of the RMB undervaluation to some extent.

The findings that under a monetary policy of RMB undervaluation, China experienced larger price changes than U.S, suggests that China has borne most of the burden from its own exchange rate undervaluation policy over the years. With a monetary policy of RMB revaluation, China is likely to import more soybean and export more soymeal, while the U.S. soybean production and exports may increase.

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