Malaysian Cocoa Market Modeling: A Combination of Econometric and System Dynamics Approach

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Not for quotation

Malaysian Cocoa Market Modeling: A Combination of Econometric and System Dynamics Approach[1]

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Abstract

The Malaysian cocoa sector has undergone dramatic changes during the last few decades. In the early years of 1970s, this sector has maintained an upward trend in the area and consequently the production. However, the trend reversed in the late 1980s due to factors such as declining world prices, higher labour costs, widespread of cocoa pod diseases and the pull of more lucrative crops (in particular palm oil). By 2008 only about 19,976 hectares were planted with cocoa compared to a peak of 414,236 ha in 1989. Production of cocoa beans has trended down accordingly. The study combines the econometric and system dynamics approach in modeling the Malaysian cocoa market. A first order system was developed to capture the interdependencies of the major structural elements of the markets such as production, local and export demands, inventory and imports. Nevertheless, the model provides an understanding of the interrelationships between the system components and allows the simulation of policy variables changes. Future work will involve a detail examination of the interaction cocoa supply chain system (from farm to export) to provide a much more comprehensive representations of the dynamics of the market.

Keywords: *Econometric methods, system dynamics, Malaysian cocoa market*

I Introduction

The Malaysian cocoa sector has undergone dramatic changes during the last few decades. In the 1970s and 1980s, the cocoa industry experienced expansion in planted areas and hence production. This was largely attributed to factors such as relatively low production cost and the smooth transfer of estate management system into large cocoa plantations. The area planted with cocoa reached its peak in 1989 at 414,236 ha (compared to a mere 4,019 ha in 1970). Since then, the area and production declined at a rapid rate due to both natural and economic factors such as the advent of cocoa pod disease in the early 1990s, continuous decline in the world cocoa price and the strong pull of lucrative crops (such as palm oil) and non-agricultural activities (Figure 1). The estate companies are migrating to more profitable crops such as palm oil leaving the smallholders manning the industry. In 1980, the smallholders accounted for 34% of the area, but by 2008, their share has increased to 84% of the total area of 19,976 ha.

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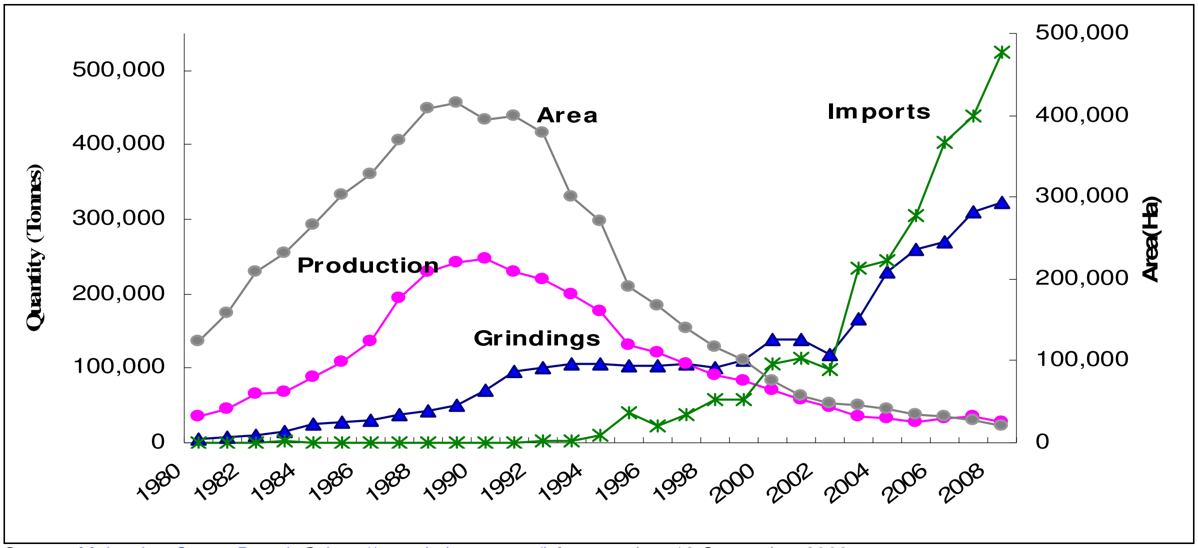
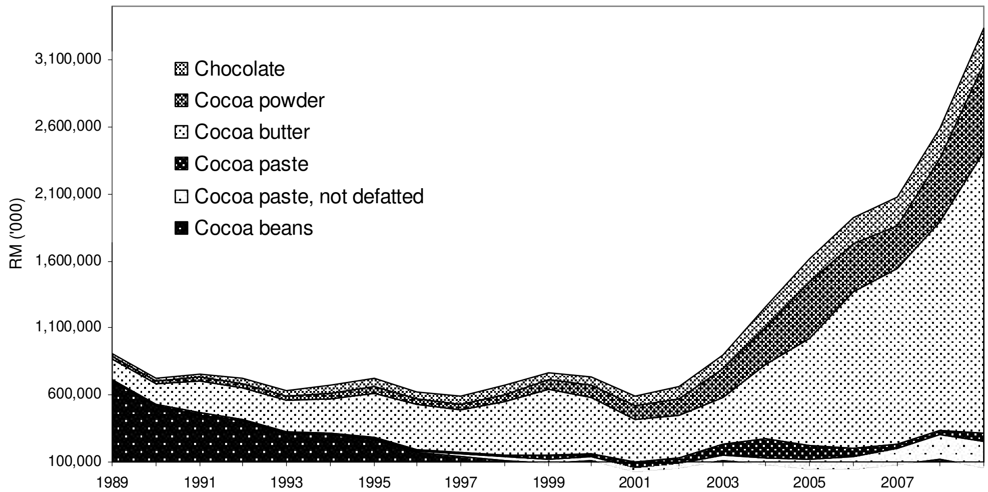


Source*:* Malaysian Cocoa Board @ *http://www.koko.gov.my/l Accessed on 12 September 2009*

Figure 1 Malaysia: Cocoa Area (ha) and Cocoa Production, Imports and Grindings (tonnes), 1980-2008

On the other hand, the Malaysian cocoa grindings and downstream industry have expanded dramatically. Currently, Malaysia, with a total grindings of 323,653 tonnes in 2008 is occupying the fifth position among the largest cocoa grinders in the world and ranked fourth in Asia. Besides local beans, Malaysia imports beans from the neighbouring countries to support its grinding and cocoa-based products industries. It is now a net exporter of cocoa products including chocolates. Malaysian cocoa products are exported to over 66 countries, including USA, Australia, France, Japan, Singapore and New Zealand. As shown in Figure 2, Malaysia's exports of cocoa-based products have increased from RM907 mn (1989) to RM3.3 bn in 2008. The figure shows the growing significance of high value cocoa-based products such cocoa butter and chocolate.



Source*: Malaysian Cocoa Board @ http://www.koko.gov.my/l Accessed on 12 September 2009*
Figure 2: Components of Cocoa Exports, 1989-2008 (RM'000)

Econometric models have been used to examine the relationship between major variables in the Malaysia cocoa industry (Rosdi, 1991, Mat Lani et al., 1993, Remali Yusoff et al., 1998, and Kox, 2000 and Mohammad Haji Alias, 2001). The technique has been proven adequate to explain the relationship between supply, demand, inventory and prices of cocoa. The application of a system dynamics approach has not been attempted despite its advantageous such as the ability to capture variables that may not be significant in the econometric equations while in the real world they exert meaningful influences. Besides, system dynamics are able to capture the feedback relationships among the variables. With the exception of Kennedy and Jahara et al., (2006), the application of system dynamics into Malaysia's commodity sector is minimal. As this technique require a wide spectrum of data (secondary, experts' view and industry) this study is an exploratory attempt to combine an econometric model of cocoa into the system dynamics approach to examine the feedback relationship between the major sectors in the industry.

The remainder of the paper is organized as follows: Section II briefly reviews the literature on previous agricultural commodity models and the relevant system dynamic modeling economic and the methodologies used for examining market models for different perennial crops. Section III outlines the empirical methodology and Section IV reports and discusses the results while a summary and some conclusions are presented in Section V.

II Literature Review

System dynamics has been developed in 1957 by Jay W. Forrester of Massachusetts Institute of Technology (MIT) as a methodology for building computer simulation models. It is a methodology to analyze complex systems and problems with the aid of the computer simulation software (Forrester, 1968). The theory, methods and philosophy are combined to analyze the behaviour of the system. The core of the modeling strategy is representation of system structure in terms of *stocks* and *flows*. In this connection, *feedback* loops are the building blocks for articulating the dynamics of these models and their interactions can represent and explain system behavior (Choucril et al., 2005). Also, it is an iterative process of identifying the structure, mapping and simulating a model. Meadows (1970) conceptualised the commodity product cycles that became the reference of all commodity dynamics analyses. He proposed the basic structure for production cycles where exogenous fluactuations propagate to cause oscillatory/cyclic behaviour and that cycles periods from the model compared well with the durations of historical commodity cycles.

Kennedy and Jahara et al., (2006) adopted system dynamics approach to examine the biodiesel, crude palm oil and petroleum prices linkages. System dynamics approach was selected to explore how the market structure and various system parameters affect the system. Three shocks were taken into consideration, i.e., the ramp-down in oil price from USD 60 per barrel to USD 40 per barrel over one year, ramp-up in oil price from USD 60 per barrel to USD 80 per barrel over one year and oscillation in Crude Palm Oil (CPO) production rate based on the annual cycle. The drop in oil price from USD 60 per barrel to USD 40 per barrel over the course of one year resulted in a decline in biodiesel demand, followed by CPO demand drop, which pushed CPO prices down. Break-even values for crude palm oil price and biodiesel demand before and after the decline were USD 358 per tonne and 321,746 tonnes per month, respectively. When crude oil price continued to decline in a year, it took four years for the CPO price and palm biodiesel demand to attain their new equilibrium; USD 340 per tonne and 104,090 tonne per month respectively. The drop in crude palm oil price resulted in an increase in the demand of Refined Palm Oil (RPO) from 2.25 million liters per month to 2.46 million litres per month. Meanwhile, there was no change in the total cultivated area because small change in profitability of CPO production did not affect the replanting rate.

Pertiwi (2003) developed an SD model that represented the inter component interaction characteristics observed in the food industry in Indonesia. The system elements included in the model were, among others, population, labour, land use, price and input technology. The likely impact of policy intervention on the food security system was examined.

Cloutier (2001) used SD approach to model the economic and production system of the maple sap products industry in Quebec. This paper adopted the structure introduced by Meadows (1970) of dynamic commodity cycle model that specifies production, price expectations, supply response, demand and inventory. The model captured the microstructure of maple sap collection and syrup production in Quebec which was used to simulate the macrobehaviour of the industry. SD model were used because of the nonlinearity and dynamic behavior in maple sap production and the long feedback delays involved in the fixed asset investments which support the sap collection and syrup production.

Osorio (2009) also applied system dynamics to examine the long term cyclical behavior of coffee price. This model was based on structure developed by Meadows (1970) and Deaton and Laroque (1996, 2003). The model included price, investments, capacity and demand to represent internal structure of the system. The behavior of the system was examined in response to the changes in the parameters such as coefficient of adaptive expectation, parameters in price formulation and delays.

The same method was adopted by Bantz and Deaton (2006) to evaluate the U.S. biodiesel industry. The supply-demand-price model was used to explain the feedback mechanisms and dynamics involved. Two sections were involved that is capacity and production inventory. The capacity section comprised construction, startup, operation and shutdown of production capacity. The production and inventory comprised of biodiesel and co-product glycerol.

Haghighi (2007 and 2008) used the combination of econometric and system dynamics approach to determine the optimal employment and production policies in the agricultural sector of Iran. A SD model were built based on the econometric relationships and also by incorporating the dynamic changes of the socio-economic variables. His model predicted a downward turn for the labour surplus in the sector in 2008 and the continuous decline after that. The impact of changes in the government policy such as exchange rate, agricultural price index on employment was shown to be significant compared to production.

III Methodology

The framework developed in this study was drawn from the combination of the econometrics method and the system dynamics approach. This section dissuces the different econometric models such as suply, demand, price and stock which will be used in the SD model. The behavioural equations describe the determination of Malaysian cocoa production, cocoa import, domestic consumption, cocoa exports and coca domestic prices. This model is closed with identities defining ending period stock level. Each of the equation will be disscussed in which the disturbance terms are suppressed for simplicity.

Table 1: Model Listing

Supply

[1] $CBPR_t = f_1 (RMCB_{t-2}, CPOP_{t-2}, GOVDE_{t-2}, IR_{t-2}, HA_t, CBPR_{t-1})$

Malaysian Cocoa Import

[2] $CBIMP_t = f_2 (WPCB_t, POWP_t, CBIMP_{t-1})$

Domestic Consumption

[3] $CBDD_t = f_3 (RMCB_t, GDPPK_t, CBDD_{t-1})$

Cocoa Exports

[4] $CBEX_t = f_4 (WPCB_t, ER_t, WGDPPK_t, WPOP_t, CBEX_{t-1})$

Cocoa Domestic Prices

[5] $RMCB_t = f_8 (CBSTOCK_t , WPCB_t, RMCB_{t-1})$

Identity

Malaysian Palm Oil Ending Stock

[6] $CBSTOCK_t = CBSTOCK_{t-1} + CBPR_t + CBIMP_t – CBDD_t – CBEX_t$

Note: Definition and classification of variables are given in Table 2.

Table 2: Definition and Classification of Variables

Variables Definition			
a. **Endogenous Variables**			
1.	$CBPR_t$	=	Cocoa production (tonnes)
2.	$CBIMP_t$	=	Import of cocoa (tonnes)
3.	$CBDD_t$	=	Domestic demand of cocoa (tonnes)
4.	$CBEX_t$	=	Malaysian export of cocoa (tonnes)
5.	$RMCB_t$	=	Domestic price of cocoa (tonnes)
6.	$CBSTOCK_t$	=	Cocoa ending Stock (tonnes)
b. **Exogenous Variables**			
1.	$RMCB_{t-2}$	=	Price of cocoa lag 2 years (RM/tonne)
2.	$CPOP_{t-2}$	=	Crude palm oil price lag two years
3.	$GOVDE_{t-2}$	=	Government agricultural and rural development expenditure lag 2 years(RM million)
4.	IR_{t-2}	=	Interest rate lag two years (%)
5.	HA_t	=	Harvested area (tonnes)
6.	$WPCB_t$	=	World price of cocoa beans
7.	$POWP_t$	=	Palm oil world price (USD/tonne)
8.	$GDPPK_t$	=	Gross Domestic Product Per Capita for Malaysia
9.	ER_t	=	Exchange rate (RM/USD)
10.	$WGDPPK_t$	=	World Gross Domestic Product Per Capita
c. **Predetermined Variables**			
1.	$CBPR_{t-1}$	=	Malaysian cocoa production lag one year (tonnes)
2.	$CBIMP_{t-1}$	=	Import demand of cocoa lag one year (tonnes)
3.	$CBDD_{t-1}$	=	Cocoa beans domestic consumption lag 1 year (tonnes)
4.	$CBEX_{t-1}$	=	Export lag one year (tonnes)
5.	$RMCB_{t-1}$	=	Domestic price of cocoa lag one year (RM/tonne)
6.	$STOCK_{t-1}$	=	Stock one period lag (tonnes)

The Augmented Dickey-Fuller (ADF), Philip Perron (PP) and Kwiatkowsky Phillips Schmidt and Shin (KPSS) tests were used to determine the order of integration of the time series in all models and to check for the presence of deterministic time-trend in each regression. The unit root tests were conducted for the variables in levels as well as in first differences form and in both cases the unit root test statistics are conducted with and without deterministic trend.

The first step of SD involves understanding about the system in the form of causal loop diagram. Then it was transformed to the system dynamic stock and flow diagram, which contains components of a system, inter component interactions and its behaviors. By using IThink software, a computer simulation model was developed and it was validated using history statistical data. In order to understand the possible problems and its solution of the system several scenarios need to be simulated (Sterman, 2000).

SD is a useful analysis tool for analyzing and studying the behaviour of complex dynamic systems by identifying the cause and effect relationships and the feedback control mechanism that creates the dynamics of a commodity system. For instance, as cocoa beans price increases, the amount of coca produced will also increase, albeit with some delay. To generate a model that can run as a simulation, this causal relationship is expressed in the econometric relationships. Model parameters such as characteristic time delays or price elasticities in addition to the model variables constitute another important component. Feedback loops become apparent as the set of variables and parameters become interconnected.

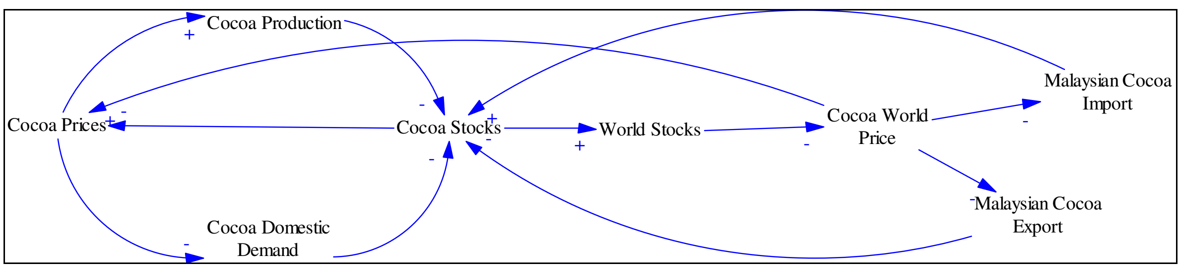


Figure 3: Causal Loop Diagram of Malaysian Cocoa Market

The causal loop diagram for cocoa is presented in Figure 3. There are three feedback loops in the cocoa market. The loops on the left represents the influence of cocoa price on the cocoa production. An increase in the cocoa prices leads to an increase in the cocoa production. A higher cocoa production leads to cocoa stocks increase where this in turn reduce the price of cocoa. The loops on the right shows the increase in cocoa stock increases world stocks of cocoa which will reduce the world cocoa price. A lower world price of cocoa increases the export demand which in turn reduces the cocoa stocks and the causal loop continues. The flow and stock diagram is shown in Figure 4.

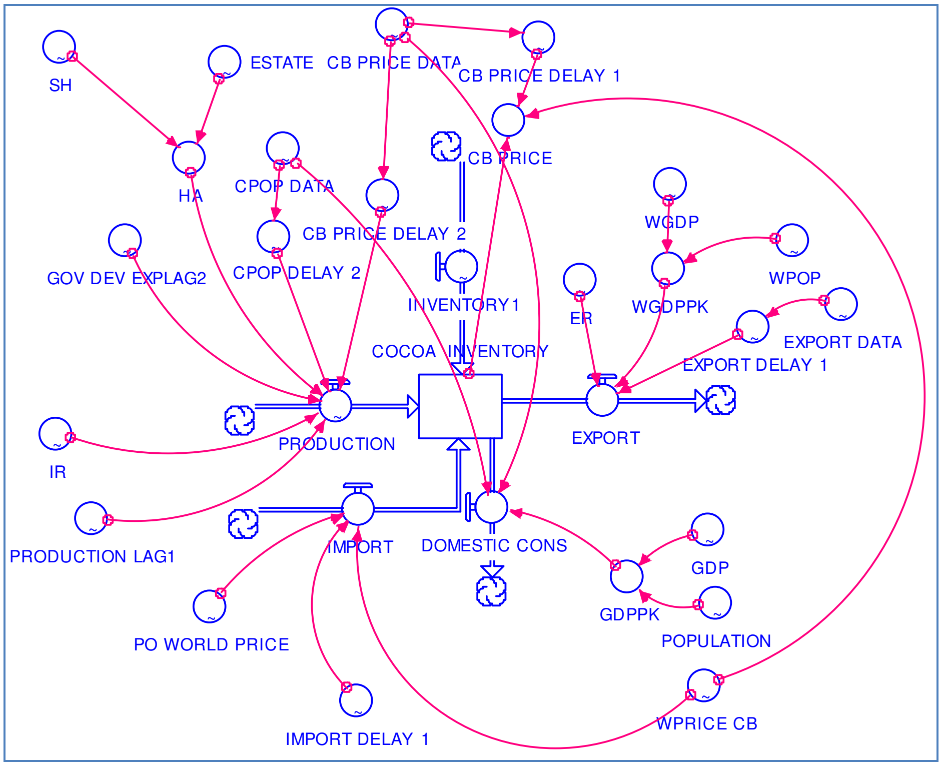


Figure 4: Stock and Flow Diagram of Supply, Demand, Price and Stock

Data Source

The primary sources of data used to estimate the econometric model are obtained from Malaysian Cocoa Board, International Financial Statistics of the International Monetary Fund and FAOSTAT. Annual data for the period 1980 to 2008 are used.

IV Results and Discussion

The non linear Two Stage Least Squares (2SLS) results obtained are quite satisfactory in terms of high R^2, significance of the coefficients of the variables and that the signs of the coefficients are consistent with *a priori* expectations. The SD cocoa model incorporates the econometric results to drive key variables such as production, domestic demand , domestic price and export demand. The stability and validity of the model to represent the general features and behaviour of the cocoa market is demonstrated through simulation experiments by its ability to emulate the historically observed behavioral patterns[3]. To understand the

[3] *The popular statistical tests showing the validity of the simulated values are Root Mean Square Percentage Error (RMSPE) and Theil's inequality coefficients (UT). The value of RMSPE calculated for the cocoa econometric model was relatively small (about 10 %) with the exception of cocoa production while the values of UT of all the endogenous variables are less than one. Thereby, the model can be assumed as a valid model.*

dynamics of the modeled system, it will be useful to test the response to external shocks that perturb the system from its equilibrium. This is done by a set of simulation experiments whereby the model is subjected to changes in the values of individual parameters. The digression of key model variables from a baseline can then be assessed.

This study chooses to simulate a change in the smalllholder growth rate (in terms of cocoa area planted) as this sub-sector has shown a rapid decline since 1990s. As at 2008, 80% of the producers were smallholders compared to 30% in 1980. Three scenarios are simulated; an increase of 5%, decline of 5% and 10% of the growth rate of the smallholder planted area. The impact of these changes on the system is shown in Figures 3 – 7. This exercise indicates that an increase of the smallholder growth rate of 5% will cause an increase in the cocoa production by about 6%, cocoa availability (cocoa stocks) also increase by 5.97% and the domestic price of cocoa will decrease 0.37%. Decrease in cocoa price will increase the domestic consumption about 0.10% which in turn will decrease the cocoa stock.

V Summary and Conclusions

The objective of this paper is to model the Malaysian cocoa market by combining econometric method and system dynamics model to provide a platform for policy variables simulations. A first order system is diagramed and the econometric parameters are inputted into the stock and flow system. The study simulates the impact of changes in the growth rate of the smallholder planted area on the system. The simulation suggests that changes in the rates will affect production and the whole system variables such as stock, domestic price, and domestic consumption. The combined method appears to be able to capture the dynamics of the major variables in the system as expected. However, the model can be further improved by a development of a comprehensive view of the cocoa system to include production, processing, grindings, marketing and pricing. The internal structure of the system at each level is to be established to derive the macro-behaviour of the system.

Appendix

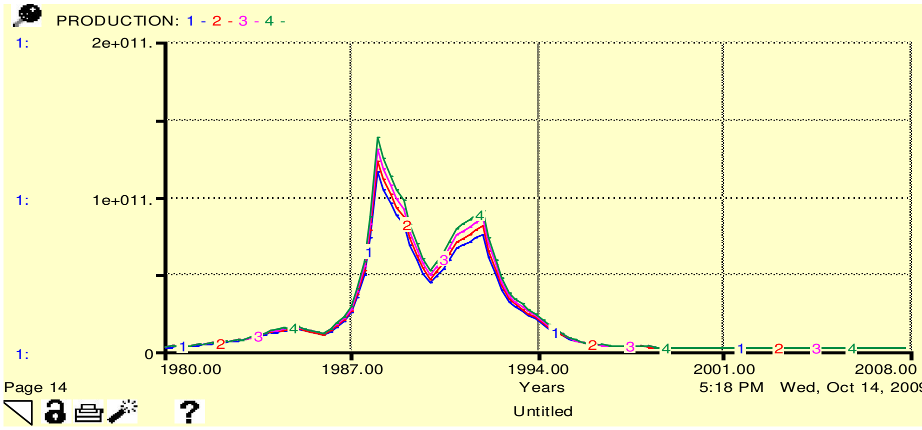


Figure 4: Changes in Cocoa Production

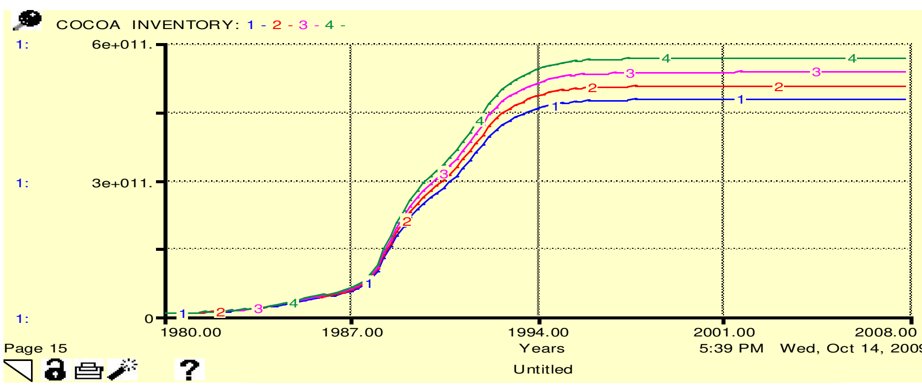


Figure 5: Changes in Cocoa Stock

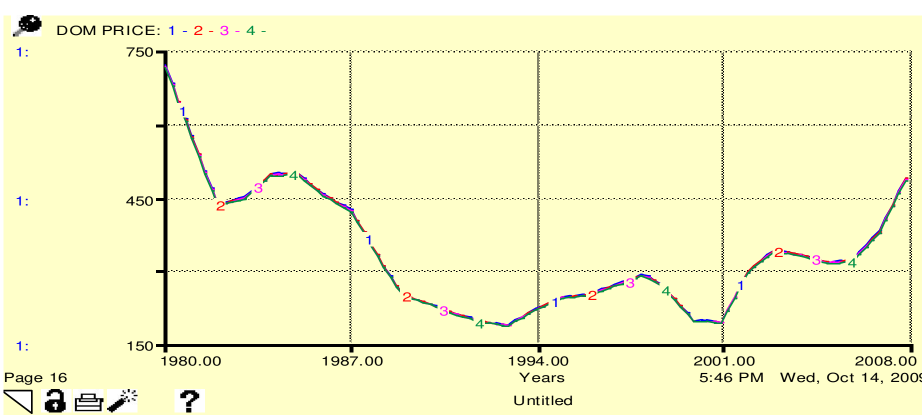


Figure 6: Changes in Cocoa Domestic Price

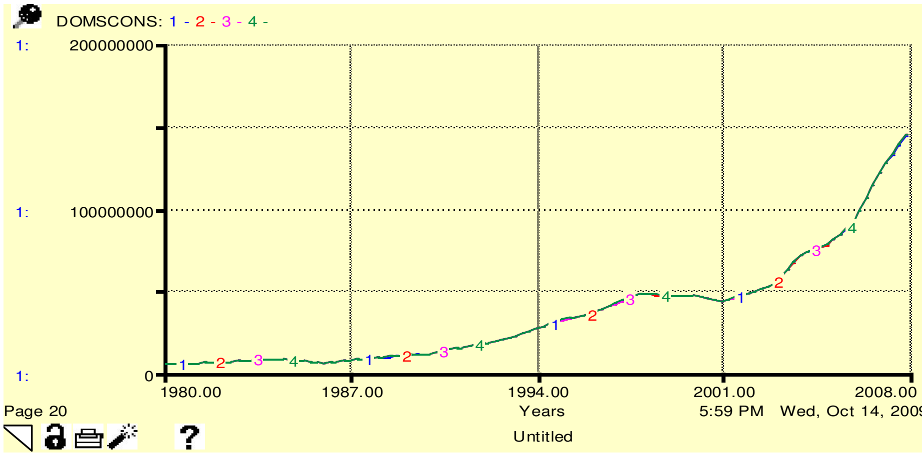


Figure 7: Changes in Cocoa Domestic Consumption

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