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How low is the price elasticity in the global cocoa market?

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Abstract:

The high volatility of the world cocoa price makes the millions of cocoa farmers in the developing world highly vulnerable to poverty. A large volatility in the value of an agricultural commodity is linked to the inelasticity of its supply or demand. Therefore, we test the hypothesis that the price elasticities of the global cocoa supply and demand are low. We describe the global cocoa market with cointegration dynamic supply, demand and price sub-models. Our OLS, 2SLS, and SUR estimates are based on annual global observations covering the years 1963 through 2013. We find that the global cocoa supply is extremely price-inelastic: the corresponding short- and long-run estimates are 0.07 and 0.57. The price elasticity of cocoa demand also falls into the extremely inelastic range: the short- and long-run estimates are −0.06 and −0.34. Based on these empirical results, we consider the prospects for cocoa price stabilization. The cocoa price volatility was treated with various unsuccessful methods in the past. A possible solution for reducing the price volatility would be the encouragement of crop diversification. This increases the price elasticity of cocoa supply by adjusting the effort and money allocation between the crops, thus decreasing price volatility.

Keywords: cocoa, supply, demand, price elasticity.

JEL codes: O13, Q11.

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1. Introduction

The soaring economic and population growth in Africa and Asia, the increase of global trade, and globalization have considerably boosted demand for cocoa beans (ICCO, 2012). However, cocoa growing countries can barely meet this expanding demand (ICCO, 2016). These sustained processes triggered extraordinary cocoa price volatility in this new century (Onumah et al., 2013). Price volatility induces uncertainty among cocoa market participants, hence preventing the market from working properly (Piot-Lepetit and M'Barek, 2011). Extreme volatility of the world cocoa price also makes the millions of cocoa farmers in the developing world highly vulnerable to poverty (Fountain and Hütz-Adams, 2015).

This study helps to inform development policies of the elements involved in the cocoa bean market to understand the roots of the recent price volatility. According to Piot-Lepetit and M'Barek (2011), a large volatility in the value of an agricultural commodity is connected to the inelasticity of its supply or demand. Therefore, we test the following two hypotheses. First, the global cocoa demand is extremely price-inelastic. Second, the price elasticity of global cocoa supply is extremely low. We model the global cocoa supply, demand, and price between 1963 and 2013 with cointegration dynamic simultaneous equations (Hsiao, 1997a and 1997b). Because OLS may not be an adequate estimation method, our model is also estimated with two other techniques: SUR (seemingly unrelated regressions) and 2SLS.

Regarding cocoa price elasticity, the papers from the last decades investigate only domestic cocoa markets over a period of 23–34 years. Shamsudin et al. (1993) and Hameed et al. (2009) analyze the Malaysian cocoa market. Furthermore, Gilbert and Varangis (2003) examine the cocoa markets in four West African countries. Moreover, Uwakonye et al. (2004) focus on Ghanaian cocoa. Our contribution to the literature, in the testing of the hypotheses above, is twofold. We integrate a number of variables from a global cocoa data set that covers half a century and carry out estimations with three different methods employing rigorous unit root, cointegration, and instrumental variable testing.

This paper is divided into six parts. We begin in part 2 with an overview of the global cocoa supply, demand, and price. Then in part 3, we review the methodologies of the previous cocoa market models and the estimation issues. Furthermore, the specification of our cocoa market model and our data sources are presented in part 4. Next, the different estimation results for the cocoa supply, demand, and price equations are reported in part 5. Last, we summarize our findings and draw a brief conclusion in part 6.

2. Background

2.1 Cocoa supply and demand

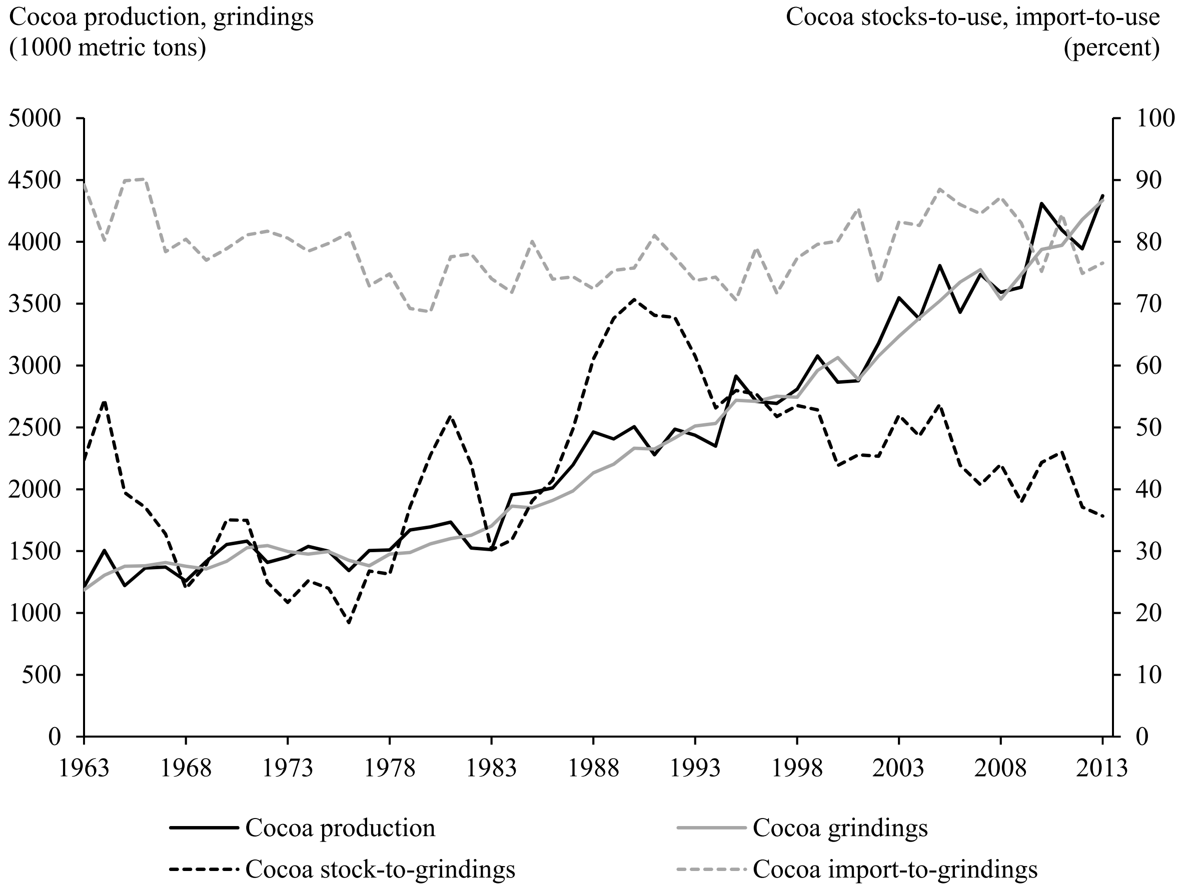
Cocoa is primarily grown by smallholders in tropical areas. Usually, cocoa trees reach their productive age around three years after planting and their yields top out at around the seventh year, but decent cocoa yields can be harvested for additional 20 years (Dand, 2011). The presumed implication of the long cocoa cycle along with no close cocoa substitutes is extremely inelastic cocoa supply (Siswoputranto, 1995). Adverse weather and pests are also major factors influencing cocoa yields: it is estimated that diseases destroy about 30 percent of the global production every year (UNCTAD, 2006).

The three main cocoa-growing and exporting nations are the Ivory Coast, Ghana, and Indonesia. In 2013, their share of the global production were 38, 20, and 9 percent, while their share of global net exports were 37, 22, and 14 percent (ICCO, 2016). Figure 1 illustrates the development of the global cocoa supply over the last half a century. Cocoa production rose from 1.3 million tons to over 4 million tons in 2013, representing an average yearly growth rate of 2.60 percent. Moreover, with yearly growth rates between -10 and 13 percent, the global cocoa production fluctuated widely around the trend line due to climatic factors.

Because of the differences between the sources of cocoa production and the uses of cocoa, over two thirds of all cocoa production is traded internationally (Figure 1). Africa is by far the leading cocoa exporter. Furthermore, the largest regional cocoa bean trade is between Africa and the EU. Europe constitutes for more than half of all net cocoa imports (ICCO, 2016), but the United States is the main importing country with a 21 percent of the world cocoa imports.

Most of the cocoa grindings take place in cocoa importing nations near the main centers of cocoa consumption. Netherlands is the leading cocoa bean processor with a 13 percent share of the world grindings. However, origin cocoa grindings are also widespread: the Ivory Coast is the second largest cocoa processor (ICCO, 2016). Figures 1 also displays the global cocoa demand between 1963 and 2013. Demand, as measured by grindings, rose on average by 2.63 percent per year over the period from 1.2 million tons to 4.3 million tons. Furthermore, cocoa grindings showed a steadier trend than cocoa supply with yearly growth rates between -7 and 10 percent. Finally, we can also see from Figure 1 that the ratio of cocoa stocks-to-grindings peaked in 1990 and has been falling ever since.

Figure 1: World cocoa production, grindings, stocks-to-grindings, and import-to-grindings (1963–2013).



Source: FAO Statistics, ICCO Quarterly Bulletin of Cocoa Statistics.

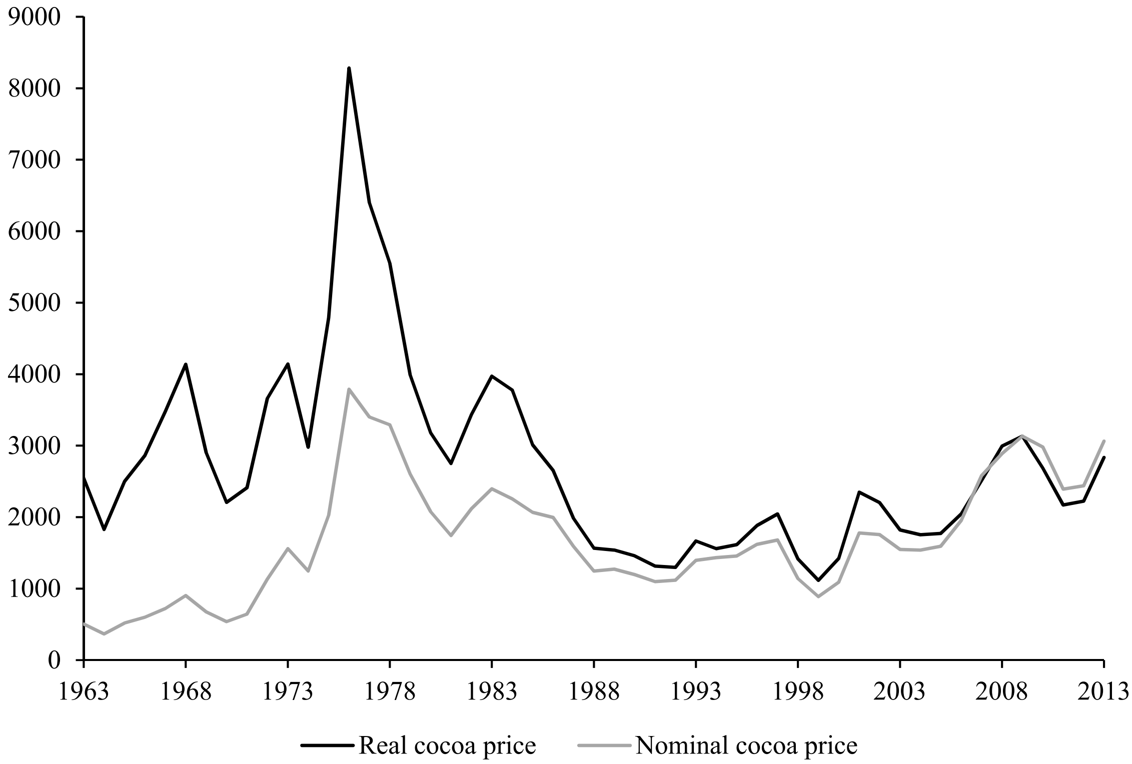
2.2 World cocoa price

The world cocoa bean price is determined at the two primary cocoa futures exchanges in New York and London. Because cocoa has very limited uses and no major substitutes, the main influencing factors of the global cocoa price are cocoa supply and demand (Dand, 2011). World cocoa prices usually reflect a long-term pattern connected to the cocoa production cycle, which is judged to be about 25 years long. In the course of cocoa booms a supply surplus is generated that results first in the fall and then in the stagnation of cocoa prices. Continuously low cocoa prices have a negative effect on harvesting, prompting cocoa farmers to shift to alternative crops. This permits world cocoa prices to rise again (Siswoputranto, 1995; UNCTAD, 2006).

The International Cocoa Organization (ICCO), whose 40 members include both exporter and importer countries, was established in 1973 to promote international cooperation, to assist a balanced evolution of the global cocoa market, and to manipulate the cocoa buffer stocks and production to stabilize world cocoa price in a zone. However, it has been ineffective in maintaining the stability of cocoa prices due to insufficient funding as well as the absence of the biggest cocoa consumer, the United States (Dand, 2011).

Figure 2 shows the development of the world cocoa price. In midst of the general global commodity boom of the 1970s, the value of cocoa beans experienced a striking increase, which later boosted cocoa production in countries such as Indonesia and Malaysia. From the beginning of the 1980s, owing to the higher cocoa stocks-to-grindings ratio (Figure 1), cocoa prices plummeted for two decades. The price bottom was reached in 2000. Then, the nominal value of cocoa rose from 888 to 3064 U.S. dollars/ton and the real value from 1116 to 2836 U.S. dollars/ton, which coincided with the drop of the cocoa stocks-to-use ratio from over 70 percent to under 40 percent. However, it can be observed that the world cocoa price is still low compared with those dominating 40 years ago, while real chocolate prices were maintained since the 1970s. The volatility of the world cocoa price, though, increased considerably in the new millennium (ICCO, 2012).

Figure 2: The real and nominal world cocoa price in US dollar/ton (1963–2013).



Source: World Bank Global Economic Monitor.

Note: The price index is Manufacture Unit Value (MUV) index from the World Bank and the base year is 2010.

3. Methodology and literature review

3.1 Commodity market models

We use the popular commodity market framework of Hallam (1990) and Labys (2006) to devise our own cocoa market model. This framework is composed of four equations. The supply, demand, and price sub-models in addition to the market equilibrium condition are the following:

$$S_t = s\,(S_{t-1}, P_{t-1}, PA_{t-1}, W_t) \quad (1)$$

$$D_t = d\,(D_{t-1}, P_t, PS_t, Y_t) \quad (2)$$

$$P_t = p\,(P_{t-1}, I_t, D_t) \quad (3)$$

$$I_t = I_{t-1} + S_t - D_t\,, \quad (4)$$

where S_t is the commodity supply, D_t is the commodity demand, P_t is the commodity price, I_t denotes the commodity inventories, PA_t indicates the prices of alternative commodities, PS_t represents the prices of substitute commodities, Y_t is income, and W_t reflects the weather effects.

In this framework, commodity supply is determined by lagged supply, lagged own price, lagged prices of alternative crops, and weather. Moreover, commodity demand depends on lagged demand, own price, prices of substitute commodities, as well as income. Furthermore, lagged commodity price, commodity inventories along with commodity demand are used to explain the commodity price. Finally, the model is closed with the commodity stocks identity which equates commodity quantity demanded with quantity supplied plus the change in commodity inventories.

The framework above is adopted in many price elasticity studies concerning tropical commodities. For example, Behnman and Adams (1976) and Hwa (1979, 1985) use it to model various cocoa, rubber, cotton, tea, coffee, and sugar markets. Because we could not find a world cocoa market model, we highlight three preceding domestic cocoa studies in the next three paragraphs.

In the first study, Hameed et al. (2009) investigate the Malaysian cocoa market between 1975 and 2008. They specify three equations: domestic cocoa supply, export demand for Malaysian cocoa, and domestic cocoa price. These equations are estimated with the SUR technique because they find no endogeneity in their model. The four main results of their paper are the following. First, the short-run price elasticities of cocoa supply and demand are low:

0.39 and –0.37. Second, palm oil is not a supply substitute for cocoa beans. Third, the world industrial production index greatly affects the cocoa export demand. Finally, the domestic cocoa price is highly determined by the world cocoa price. The weakness of their findings is that they do not use unit root and cointegration tests.

In the second study, Uwakonye et al. (2004) focus on Ghanaian cocoa over the period 1980–2002. They estimate two equations, domestic cocoa supply and cocoa export demand, with the 2SLS method. Their results also suggest price-inelastic cocoa supply and demand: the corresponding estimates are 0.26 and –0.54. Additionally, they find that the domestic cocoa supply is highly influenced by the world corn price. Moreover, sugar does not turn out to be a cocoa demand substitute in their paper. Finally, the world GDP is highly significant in explaining the cocoa export demand in their model. The weakness of their paper is that they do not apply any unit root, cointegration, or instrumental variables tests.

In the third study, Gilbert and Varangis (2003) examine the cocoa market of the Ivory Coast between 1969 and 1999. By applying the FIML method, they estimate three equations: domestic cocoa supply, world cocoa demand, and domestic cocoa price. Their results also point to the low short-run price elasticities of cocoa supply (0.43) and demand (–0.10). Surprisingly, the world GDP does not shift the world cocoa demand in their model. Finally, they find that the domestic cocoa price in the prior year considerably affects its current value. The weakness of their results is that they do not test for unit roots and cointegration.

3.2 Estimation issues and tests

In the case of a commodity market framework, it is expected that several variables (commodity supply, commodity demand, commodity price, and commodity inventories) are simultaneously determined (Hallam, 1990). This means that these variables are endogenous. By using instrumental variables (IV), the 2SLS approach is the most common estimation method of simultaneous equations models. Still, it is at least of passing interest to examine the results of the OLS estimation, despite its inconsistency.

Using the 2SLS method, an important question to ask is whether regressors assumed to be endogenous could rather act as exogenous. If the endogenous variables are exogenous then the OLS estimation method is more efficient and we may sacrifice a considerable amount of efficiency with the use of an IV method, thus OLS should be used instead. Therefore, we test for endogeneity with Eichenbaum et al. (1988) method.

Furthermore, excluded exogenous regressors can be valid instrumental variables only if they are sufficiently correlated with the included endogenous variables. Weakly correlated instruments can lead to bias toward the OLS inference and the standard errors reported can be severely misleading, as well. Therefore, we test the strength of the instruments with the Kleibergen and Paap (2006) method. Its test statistic does not follow a standard distribution, but Stock and Yugo (2005) present a table with critical values for some combinations of instrumental and endogenous variable numbers.

The second validity condition of instrumental variables is that they are not correlated with the error term. However, we can assess this only if the model is overidentified, i.e., the number of instrumental variables is larger than the number of endogenous variables. We evaluate with the Hansen (1982) test whether the second validity premise holds for a subgroup of the instrumental variables but not for the remaining instruments.

Using time series variables, non-stationarity can create severe problems for standard inference methods. Hsiao (1997a, 1997b) provides an updated view of structural equations that takes into consideration non-stationarity and cointegration. His three key conclusions are the following. First, a legitimate drawback (simultaneity bias) also arises in OLS when regressors are integrated. Second, identification conditions for stationary variables hold for integrated ones under proper premises. Third, conventional IV formulas can be applied in parameter estimations, formulating Wald statistics, and testing procedures.

We employ the autoregressive distributed lag (ARDL) bounds framework (Pesaran et al., 2001) to test for cointegration instead of the Johansen procedure, because the latter suffers from serious flaws when regressors are not integrated of the same order. In contrast, the ARDL bounds approach yields unbiased and efficient results in small sample sizes irrespective of whether the underlying variables are stationary or integrated. This method estimates the following equation if there is only one independent variable:

$$\Delta \ln Y_t = \propto_0 + \sum_{i=1}^{n} \beta_i \Delta ln Y_{t-i} + \sum_{i=0}^{n} \gamma_i \Delta ln X_{t-i} + \lambda_1 ln Y_{t-1} + \lambda_2 ln X_{t-1} + \varepsilon_{1,t} \quad (5)$$

The first component of the equation with β_i and γ_i reflects the short-term relationships of the model whereas the parameters λ_1, λ_2 represent the long-term dynamics. The null hypothesis of the model is: $H_0: \lambda_1 = \lambda_2 = 0$ (there are no long-term relationships).

The asymptotic distribution of the obtained F-statistic is nonstandard. It is compared with the lower and upper bounds of critical F-values determined by Pesaran et al. (2001). If the test statistic is smaller than the lower bound, the null hypothesis is accepted. Similarly, if the test statistic is larger than the upper bound, the null hypothesis is rejected. However, if the test statistic falls between these two bounds, the results are ambiguous. If there is evidence that the variables are cointegrated, we estimate the long-term model:

$$\ln Y_t = \propto_1 + \sum_{i=1}^{n} \beta_i lnY_{t-i} + \sum_{i=0}^{n} \gamma_i lnX_{t-i} + \varepsilon_{2,t} \ . \quad (6)$$

Otherwise we should take first differences to estimate the short-run model:

$$\Delta\ln Y_t = \propto_2 + \sum_{i=1}^{n} \beta_i \Delta lnY_{t-i} + \sum_{i=0}^{n} \gamma_i \Delta lnX_{t-i} + \varepsilon_{3,t} \ . \quad (7)$$

4. Empirical specification

4.1 Cocoa market model

Based on the commodity market framework of Labys (2006) and the earlier cocoa market models, we describe the world cocoa bean market with three structural equations in addition to the annual ending stocks identity. The cocoa supply, demand, and price equations are the following:

$$Supply_t = \beta_0 + \sum_{n=0}^{7}(\beta_{1n} CocoaPrice_{t-n} + \beta_{2n} CoffeePrice_{t-n}) + \beta_3 Yield_t + \sum_{m=1}^{2} \beta_{4m} Supply_{t-m} + \varepsilon_{t1} \quad (8)$$

$$Demand_t = \gamma_0 + \gamma_1 CocoaPrice_t + \gamma_2 PalmoilPrice_t + \gamma_3 GDP_t + \gamma_4 Demand_{t-1} + \varepsilon_{t2} \quad (9)$$

$$Cocoaprice_t = \delta_0 + \delta_1 Stocks_t + \delta_2 Demand_t + \delta_3 Cocoaprice_{t-1} + \varepsilon_{t3} \quad (10)$$

$$Supply_t = Demand_t + Stocks_t - Stocks_{t-1}. \quad (11)$$

It is assumed that the ε_{t1}, ε_{t2}, ε_{t3} stochastic disturbances, which express random effects, a number of separately unimportant omitted regressors and measurement errors, are homoscedastic, not autocorrelated, and exhibit normal distributions:

$\varepsilon_{tj} \sim \mathcal{N}(0, \sigma_j)$, for all $t = 1 \dots T$ and $E(\varepsilon_{mj}\varepsilon_{nj}) = 0$ for all $m, n = 1 \dots T,\ m \neq n,\ j = 1, 2, 3$.

We specify a dynamic cocoa market model containing both autoregressive and distributed lag components (ARDL), since cocoa farmers and firms spread their responses over time due to adjustment costs and incomplete and lagged information. It includes four jointly determined variables (cocoa supply, cocoa demand, cocoa price, and cocoa stocks), four exogenous variables (cocoa yield, coffee price, palm oil price, and world GDP) and many predetermined variables. Furthermore, we formulate the model in double-log functional form, implying that we can approximate relationships in constant-elasticity form.

In the cocoa supply equation, the current and the lagged values of the cocoa price correspond to the short-run harvesting and the long-run farm investment decisions (Shamsudin et al., 1993). We include seven lags for the prices because cocoa trees reach full bearing capacity at the age of seven years. Based on Dand (2011), the coffee price in the cocoa supply sub-model denotes the battle for acreage. We expect that this variable has a negative effect on cocoa production. Moreover, the cocoa yield variable accounts for weather, diseases, and technological advances in cocoa cultivation. Finally, the autoregressive part in the supply model depicts the long-run constraints of cocoa production (Shamsudin et al., 1993).

In the cocoa demand equation, we assume that palm oil is a substitute for cocoa in the manufacture of chocolate because European laws accept a 5 percent content of palm oil in chocolate products (Dand, 2011). Moreover, the world GDP captures the effect of the economic activity on the global cocoa demand. Finally, the autoregressive part in the demand sub-model indicates that cocoa processing adjusts only gradually to changes due to institutional and technological rigidities (Hameed et al., 2009). For instance, sizable cocoa inventories are acquired by chocolate manufacturers to weather price increases (Dand, 2011).

In the cocoa price equation, the price clears the market in a partial adjustment process. Based on Hameed et al. (2009), we stipulate the world cocoa price as a function of annual cocoa ending stocks, cocoa demand, and lagged cocoa price. Because of the four endogenous variables, one more equation is needed in our cocoa market model. Thus, the market equilibrium condition completes the model: it equates the cocoa supply with the cocoa demand plus the change in the annual cocoa ending stocks.

4.2 Data description

Our cocoa market model estimates are based on annual global observations covering the years 1963 through 2013. We compose this data set from various sources. The cocoa production and grindings data stem from FAO Statistics and ICCO Quarterly Bulletin of Cocoa Statistics. Furthermore, the benchmark commodity prices are drawn from World Bank's Global Economic Monitor, UNCTAD Statistics, and IMF International Financial Statistics. The variable descriptions in addition to the units of measurement are presented in Table 1.

A crucial issue we need to tackle is the exact definition of our variables. The measure of a particular commodity world price can be calculated in numerous ways based on various futures, export, or auction prices from different countries. We decide to use the most widespread variable definitions. For example, the world cocoa price is derived from the nearest three trading months on two key cocoa futures markets. Furthermore, we use the ex-dock New

York Arabica/Robusta coffee composite price as the world coffee price. Additionally, the 5-percent-bulk CIF Rotterdam palm oil price in Malaysia represents the world palm oil price.

Table 1: Description of the cocoa market variables.

Variable	Description
Supply	World cocoa bean crop (in 1000 metric tons)
Yield	World cocoa bean yield (in kilograms/hectare)
Demand	World cocoa bean grindings (in 1000 metric tons)
Stocks	World cocoa bean ending stocks (in 1000 metric tons)
Cocoa price	Average of real daily cocoa futures prices: New York/London (in US dollars/metric ton)
Coffee price	Average of real daily ex-dock coffee prices: New York (in US dollars/metric ton)
Palm oil price	Average of real daily CIF Rotterdam palm oil prices: Malaysia (in US dollars/metric ton)
GDP	World real GDP (in billion US dollars)

Another issue we are confronted with is the selection of the price deflator to form real commodity prices. In this matter, we accept the recommendation of the World Bank to calculate with its Manufactures Unit Value Index for imported goods. Furthermore, we obtain the real world GDP from the World Bank World Development Indicators (WDI) to capture the effect of economic activity level. Table 2 provides the summary statistics for all the variables in our global cocoa market model before taking natural logarithms.

Table 2: Summary statistics of the cocoa market variables.

Variable	Observations	Mean	Standard deviation	Minimum	Maximum
Supply	51	2430	960	1221	4373
Yield	51	384	47	266	461
Demand	51	2389	947	1305	4335
Stocks	51	1069	535	263	1892
Cocoa price	51	2742	1362	1116	8283
Coffee price	51	3533	1730	1285	11048
Palm oil price	51	681	255	290	1518
GDP	51	38641	17225	13793	72970

Sources: FAOStat, ICCO Quarterly Bulletin of Cocoa Statistics, UNCTADStat, World Bank Pink Sheet, World Bank WDI.

Notes: We deflate the commodity prices with the MUV Index of the World Bank. The base year is 2010.

We assess the stationarity of variables with DF–GLS (Elliott et al., 1996) and KPSS (Kwiatkowski et al., 1992) tests, and, to consider one structural break, with Zivot and Andrews (1992) tests. The KPSS tests have a null hypothesis of stationarity, while the DF–GLS tests have a null hypothesis of unit root. Furthermore, the Zivot–Andrews tests have a null hypothesis of unit root without structural break. The results of the three unit root tests are mostly consistent. We find that nearly all the variables at level are integrated and none of our variables have unit roots in first differenced form (Table 3). Additionally, we test for cointegration with the ARDL bounds technique (Pesaran et al., 2001). Table 4 reports the results: the cocoa market equations represent cointegrating relationships.

Table 3: Unit root tests of the cocoa market variables.

Variable	KPSS		DF–GLS		Zivot–Andrews		
	Without trend	With trend	Without trend	With trend	Break in const.	Break in trend	Break in both
Supply	1.980***	0.214**	1.518	−2.970*	−6.045***	−5.882***	−7.160***
Yield	1.640***	0.270***	0.020	−1.678	−6.070***	−6.494***	−6.982***
Demand	1.980***	0.302***	2.427	−1.838	−4.088	−3.930	−4.147
Stocks	1.680***	0.186**	−0.423	−1.890	−3.382	−2.553	−3.457
Cocoa price	0.629**	0.191**	−1.326	−1.406	−3.500	−2.084	−3.140
Coffee price	0.899***	0.157**	−2.038*	−2.261	−3.756	−2.736	−3.345
Palm oil price	0.821***	0.242***	−0.992	−1.024	−2.576	−2.399	−3.552
GDP	1.980***	0.392***	1.699	−0.706	−3.021	−3.350	−3.130
ΔSupply	0.046	0.035	−6.554***	−6.539***	−8.276***	−7.654***	−8.204***
ΔYield	0.167	0.038	−7.686***	−7.390***	−9.420***	−9.006***	−9.451***
ΔDemand	0.081	0.071	−4.904***	−4.910***	−7.269***	−7.098***	−8.226***
ΔStocks	0.078	0.070	−4.327***	−4.296***	−6.927***	−6.327***	−6.878***
ΔCocoa price	0.063	0.063	−5.849***	−6.104***	−8.216***	−7.106***	−8.164***
ΔCoffee price	0.077	0.076	−4.844***	−4.832***	−7.033***	−6.522***	−7.008***
ΔPalm oil price	0.119	0.048	−7.864***	−8.492***	−9.589***	−9.505***	−9.603***
ΔGDP	0.872***	0.115	−2.816***	−4.908***	−6.464***	−6.130***	−6.445***

Notes: The KPSS tests (Kwiatkowski et al., 1992) employ the Quadratic Spectral kernel with automatic bandwidth selection. In the Zivot and Andrews (1992) and DF–GLS (Elliott et al., 1996) tests, the Schwarz information criterion selects the lag length with a maximum of 10 lags.

* $p < 0.1$. ** $p < 0.05$. *** $p < 0.01$.

Table 4: Cointegration tests of the cocoa market model.

Model	Without trend	With trend
Supply equation	6.92 [3.23, 4.35]***	2.33 [4.01, 5.07]
Demand equation	2.46 [3.23, 4.35]	26.81 [4.01, 5.07]***
Cocoa price equation	22.36 [3.79, 4.85]***	47.97 [4.87, 5.85]***

Notes: The statistics are the F-values of the bounds cointegration technique (Pesaran et al., 2001). The numbers in brackets are the critical lower and upper bounds at the 5 percent significance level. The tests use the Bartlett kernel with Newey−West automatic bandwidth selection and small-sample adjustments.
* $p < 0.1$. ** $p < 0.05$. *** $p < 0.01$.

5. Results and discussion

5.1 Estimator selection

First, we estimate the cocoa market model with the OLS and 2SLS methods (Tables 6, 7, and 8). In the 2SLS estimation, the instruments consist of the lagged endogenous variables. This means that all the equations are overidentified. Furthermore, the instrumental variable tests show proper instrument choices (Table 5). However, similar to Hameed et al. (2009), we find no endogeneity problem in our model. Therefore, both the OLS and 2SLS methods are consistent, but the OLS is more efficient.

Table 5: Instrumental variables tests of the cocoa market model.

Model	Weak instruments test	Overidentifying restrictions test	Endogeneity test
Supply equation	27.70	0.1473	0.7135
Demand equation	192.58	0.2854	0.7136
Cocoa price equation	133.81	0.1546	0.9485

Notes: The weak instruments test statistics are the F-values of the Kleibergen and Paap (2006) method. Furthermore, the overidentifying restrictions and the endogeneity test statistics are the p-values of the Hansen (1982) and Eichenbaum et al. (1988) methods. The tests use the Bartlett kernel with Newey−West automatic bandwidth selection and small-sample adjustments. The instruments consist of the lagged endogenous variables: $Supply_{t-1}$, $Demand_{t-1}$, Cocoa $price_{t-1}$, and $Stocks_{t-1}$. The endogeneity tests have a null hypothesis of exogeneity, and the overidentifying restrictions tests have a null hypothesis of instrument exogeneity. As a rule of thumb, the instruments are weak if the Kleibergen and Paap F-statistic is smaller than 10.

We reestimate the cocoa market model with the seemingly unrelated regressions (SUR) method for efficiency gains. This system estimation method is appropriate when all regressors are assumed to be exogenous. It takes into account contemporaneous correlations in the errors across equations and heteroscedasticity (Greene, 2011). In contrast to the 2SLS technique, we find that the OLS and SUR methods produce largely coherent results. However, we reject the hypothesis of the SUR approach that the regressions are related because the p-value of the Breusch and Pagan (1980) test for independent equations is 0.136. Therefore, we discuss only the OLS results in detail.

5.2 Cocoa supply model

The estimates of the cocoa supply model are presented in Table 6. We find that all significant coefficients carry the a priori anticipated signs. According to our results, the current and lagged prices of cocoa beans are significant determinants of the global cocoa production. They reflect the effect of the short-run harvesting and the long-run farm investment decisions. Furthermore, we find that the world cocoa supply is extremely price-inelastic: the corresponding short- and long-run estimates are 0.07 and 0.57.[1] We attribute this to the long cocoa production cycle and the large fixed farm investments (Dand, 2011).

In addition, the prices of coffee lagged three and seven years are also factors influencing cocoa supply, which reveals that farmers decide about crop production many years in advance. However, coffee appears to be a weak cocoa supply substitute. This is a plausible result: the land suitable for cocoa is very able to support coffee, but uprooting and replanting an existing plantation costs labor, time, and money, and the new crop gives no return for a couple of years (Dand, 2011).

Moreover, the yield of cocoa turns out to be a significant factor in the cocoa supply model due to its explicit association with production. Finally, the previous years' cocoa production also emerges as a major determinant. Agreeing with the national cocoa market models, supply adjusts slowly to its equilibrium value, again partially as a result of the long cultivation process.

[1] To compute long-term elasticities, the lagged values of the explained variables are equated with the current values of the regressands.

Table 6: Estimates of the cocoa supply equation.

Variable	OLS	2SLS	SUR
Cocoa price$_t$	0.069 (0.027)**	0.254 (0.066)***	0.090 (0.040)**
Cocoa price$_{t-1}$	0.083 (0.060)	−0.130 (0.117)	0.060 (0.058)
Cocoa price$_{t-2}$	−0.026 (0.050)	0.084 (0.089)	−0.029 (0.060)
Cocoa price$_{t-3}$	0.079 (0.038)**	0.070 (0.044)	0.083 (0.058)
Cocoa price$_{t-4}$	−0.042 (0.037)	−0.039 (0.075)	−0.048 (0.057)
Cocoa price$_{t-5}$	0.005 (0.035)	−0.002 (0.065)	0.008 (0.055)
Cocoa price$_{t-6}$	0.013 (0.041)	0.013 (0.060)	0.013 (0.050)
Cocoa price$_{t-7}$	0.029 (0.018)	0.045 (0.021)**	0.028 (0.038)
Coffee price$_t$	−0.078 (0.051)	−0.150 (0.051)***	−0.077 (0.035)**
Coffee price$_{t-1}$	0.063 (0.068)	0.119 (0.092)	0.066 (0.038)*
Coffee price$_{t-2}$	−0.032 (0.052)	−0.055 (0.062)	−0.033 (0.038)
Coffee price$_{t-3}$	−0.071 (0.032)**	−0.088 (0.028)***	−0.062 (0.037)*
Coffee price$_{t-4}$	0.004 (0.030)	−0.001 (0.032)	0.004 (0.038)
Coffee price$_{t-5}$	−0.024 (0.032)	−0.026 (0.036)	−0.024 (0.036)
Coffee price$_{t-6}$	0.042 (0.032)	0.086 (0.033)**	0.041 (0.036)
Coffee price$_{t-7}$	−0.095 (0.035)**	−0.162 (0.053)***	−0.093 (0.039)**
Yield$_t$	1.022 (0.118)***	1.254 (0.101)***	1.013 (0.108)***
Supply$_{t-1}$	0.410 (0.056)***	0.504 (0.067)***	0.429 (0.080)***
Supply$_{t-2}$	0.331 (0.067)***	0.165 (0.083)*	0.322 (0.089)***
R^2	0.991	0.987	0.991

Notes: Small-sample standard errors are in parentheses. The OLS and 2SLS statistics use the Bartlett kernel with Newey−West automatic bandwidth selection. The instruments consist of the lagged endogenous variables: Supply$_{t-1}$, Demand$_{t-1}$, Cocoa price$_{t-1}$, and Stocks$_{t-1}$.
* $p < 0.1$. ** $p < 0.05$. *** $p < 0.01$.

5.3 Cocoa demand model

The estimated cocoa demand parameters along with their statistical significances are shown in Table 7. Conforming to our hypothesis, they indicate that the world cocoa demand is negatively linked to the world cocoa price and the connection between the two variables is statistically significant. Furthermore, the own-price elasticity of cocoa demand falls into the extremely inelastic range: the corresponding short- and long-run estimates are −0.06 and −0.34.

We attribute this to the luxury good nature of cocoa and also to the fact that chocolate bars and confectionary products contain less than 10 percent cocoa by value (Dand, 2011).

In addition, our results show that the global cocoa demand is sensitive to the world palm oil price: chocolate manufacturers are induced to shift away from cocoa if it becomes more expensive relative to palm oil. However, the magnitude of the coefficient (0.036) concludes that palm oil is a weak demand substitute. The substitution of cocoa with vegetable oils is limited because of the legal restrictions and the unique properties of cocoa butter (Dand, 2011).

Similar to the previous cocoa country studies, we find that the economic activity level has a significant positive effect on cocoa demand. This is expected since most of the cocoa bean consumption is to feed the grinding industry and consumers with a rising income buy more cocoa products. However, our long-term GDP coefficient (0.721) falls into the inelastic range.

Finally, the parameter of the lagged cocoa demand is statistically significant in our estimation. Its value (0.817) signals that global cocoa processing adapts slowly to its equilibrium level. This is a plausible result: cocoa firms spread their responses over time due to incomplete information and additional costs (Shamsudin, 1998).

Table 7: Estimates of the cocoa demand equation.

Variable	OLS	2SLS	SUR
Cocoa $price_t$	−0.063 (0.021)***	−0.058 (0.028)**	−0.033 (0.020)*
Palm oil $price_t$	0.036 (0.011)***	0.032 (0.017)*	0.014 (0.019)
GDP_t	0.132 (0.030)***	0.124 (0.025)***	0.224 (0.061)***
$Demand_{t-1}$	0.817 (0.042)***	0.828 (0.038)***	0.744 (0.072)***
R^2	0.992	0.992	0.992

Notes: Small-sample standard errors are in parentheses. The OLS and 2SLS statistics use the Bartlett kernel with Newey−West automatic bandwidth selection. The instruments consist of the lagged endogenous variables: $Supply_{t-1}$, $Demand_{t-1}$, Cocoa $price_{t-1}$, and $Stocks_{t-1}$.

* $p < 0.1$. ** $p < 0.05$. *** $p < 0.01$.

5.4 Cocoa price model

The results of the cocoa price model estimations are displayed in Table 8. They show that the short-term stocks and consumption elasticities of the world cocoa price are −0.517 and 0.547. Furthermore, we find that their long-term counterparts are rather high with absolute values exceeding 1.5. In the domestic cocoa studies, these elasticities are usually insignificant, owing to the vast influence of the world cocoa price (Hameed, 2009).

In addition, the coefficient of the lagged cocoa price (0.660) indicates that the adjustment process to achieve the equilibrium is relatively slow. It is slower than for most agricultural commodities and is comparable to industrial commodities (Radetzki, 2008).

Table 8: Estimates of the cocoa price equation.

Variable	OLS	2SLS	SUR
$Stocks_t$	−0.517 (0.041)***	−0.701 (0.064)***	−0.534 (0.099)***
$Demand_t$	0.547 (0.070)***	0.797 (0.094)***	0.647 (0.169)***
Cocoa $price_{t-1}$	0.660 (0.030)***	0.617 (0.046)***	0.710 (0.076)***
R^2	0.830	0.817	0.850

Notes: Small-sample standard errors are in parentheses. The OLS and 2SLS statistics use the Bartlett kernel with Newey−West automatic bandwidth selection. The instruments consist of the lagged endogenous variables: $Supply_{t-1}$, $Demand_{t-1}$, Cocoa $price_{t-1}$, and $Stocks_{t-1}$.
* $p < 0.1$. ** $p < 0.05$. *** $p < 0.01$.

6. Conclusion

The economic and population growth in Africa and Asia have largely boosted the world demand cocoa and triggered an extraordinary volatility in the world cocoa price in this new century. This price volatility makes the millions of cocoa farmers in the developing world highly vulnerable to poverty. A large volatility in the value of an agricultural commodity is linked to the inelasticity of its supply or demand. Therefore, we test the hypothesis that the price elasticities of the global cocoa supply and demand are low.

We describe the world cocoa market is described with three cointegration dynamic structural sub-models (supply, demand, and price) in addition to the market equilibrium condition identity. Integrating a number of variables from a global data set that covers half a century (1963–2013), we estimate the models with the OLS, 2SLS, and SUR methods. Furthermore, we employ rigorous unit root, cointegration, and instrumental variable testing.

Our results compare favorably with theory: all significant variables carry the a priori expected signs. Furthermore, we find that the world cocoa supply is extremely price-inelastic: the corresponding short- and long-run estimates are 0.07 and 0.57. In addition, coffee appears to be a weak cocoa supply substitute. The price elasticity of global cocoa demand also falls into the extremely inelastic range: the short- and long-run estimates are −0.06 and −0.34. Finally, palm oil seems to be a weak cocoa demand substitute.

Based on these empirical results, we consider the prospects for cocoa price stabilization. The cocoa price volatility resulting from factors above was treated with various unsuccessful methods in the past: planned economies, marketing boards, and explicit supply or price manipulations (Dand, 2011). These experiments caused inefficiencies, lead to market failures, and are unlikely to win wide support (Sarris and Hallam, 2006). In 1973, the International Cocoa Organization (ICCO) was established to manipulate the global cocoa buffer stocks and production to stabilize world cocoa price in a zone. However, it has been ineffective in maintaining the stability of cocoa prices due to insufficient funding as well as the absence of the biggest cocoa consumer, the United States (Dand, 2011). According to Piot-Lepetit and M'Barek (2011), a possible solution for reducing the price volatility would be the encouragement of crop diversification. This increases the price elasticity of cocoa supply by adjusting the effort and money allocation between the crops, thus decreasing price volatility.

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