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

Andras Tothmihaly

Department of Agricultural Economics and Rural Development, University of Göttingen, Gottingen, Germany. E-mail: andras.tothmihaly@gmail.com

**Abstract**

*The high volatility of the world cocoa price makes the millions of African cocoa farmers 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 by way of supply, demand and stock sub-models. Our estimates are based on annual global observations covering the years 1963 through 2013, and three estimation methods. We find that the global cocoa supply is extremely price-inelastic: the corresponding short- and long-run estimates are 0.07 and 0.57 respectively. 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 respectively. Our assessment also shows that the low global cocoa stock levels amplify the price volatility of cocoa.*

**Key words**: cocoa; supply; demand; price elasticity

## 1. Introduction

The soaring economic and population growth in Africa and Asia, the increase in global trade, and globalisation have considerably boosted demand for cocoa beans (ICCO 2012). However, cocoa-growing countries can barely meet this expanding demand (ICCO 2016). These sustained processes have increased cocoa price volatility in this new century (Onumah *et al.* 2013). Price volatility induces uncertainty among participants in the cocoa market, hence preventing the market from working properly (Piot-Lepetit & M'Barek 2011). High volatility of the world cocoa price also makes the millions of African cocoa farmers highly vulnerable to poverty (Fountain & 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, 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 report only on domestic cocoa markets over a period of 23 to 34 years. Shamsudin *et al.* (1993) and Hameed *et al.* (2009) analyse the Malaysian cocoa market, while Gilbert and Varangis (2003) examine the cocoa markets in four West African countries. Furthermore, 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 dataset 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, price, and price volatility. Then, in part 3, we review the methodologies of the previous cocoa market models and the estimation issues. 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 stock equations are reported in part 5. Last, we summarise 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 an 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% 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 was 38%, 20% and 9% respectively, while their share of global net exports was 37%, 22% and 14% respectively (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%. Moreover, with yearly growth rates between -10% and 13%, 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 more than half of all net cocoa imports (ICCO 2016), but the United States is the main importing country, with 21% of the world cocoa imports.

Most of the cocoa grinding takes place in cocoa-importing nations near the main centres of cocoa consumption. Netherlands is the leading cocoa bean processor, with a 13% share of the world grindings. However, origin cocoa grindings are also widespread: the Ivory Coast is the second largest cocoa processor (ICCO 2016). Figure 1 also displays the global cocoa demand between 1963 and 2013. Demand, as measured by grindings, rose by 2.63% per year on average over this 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%. 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.
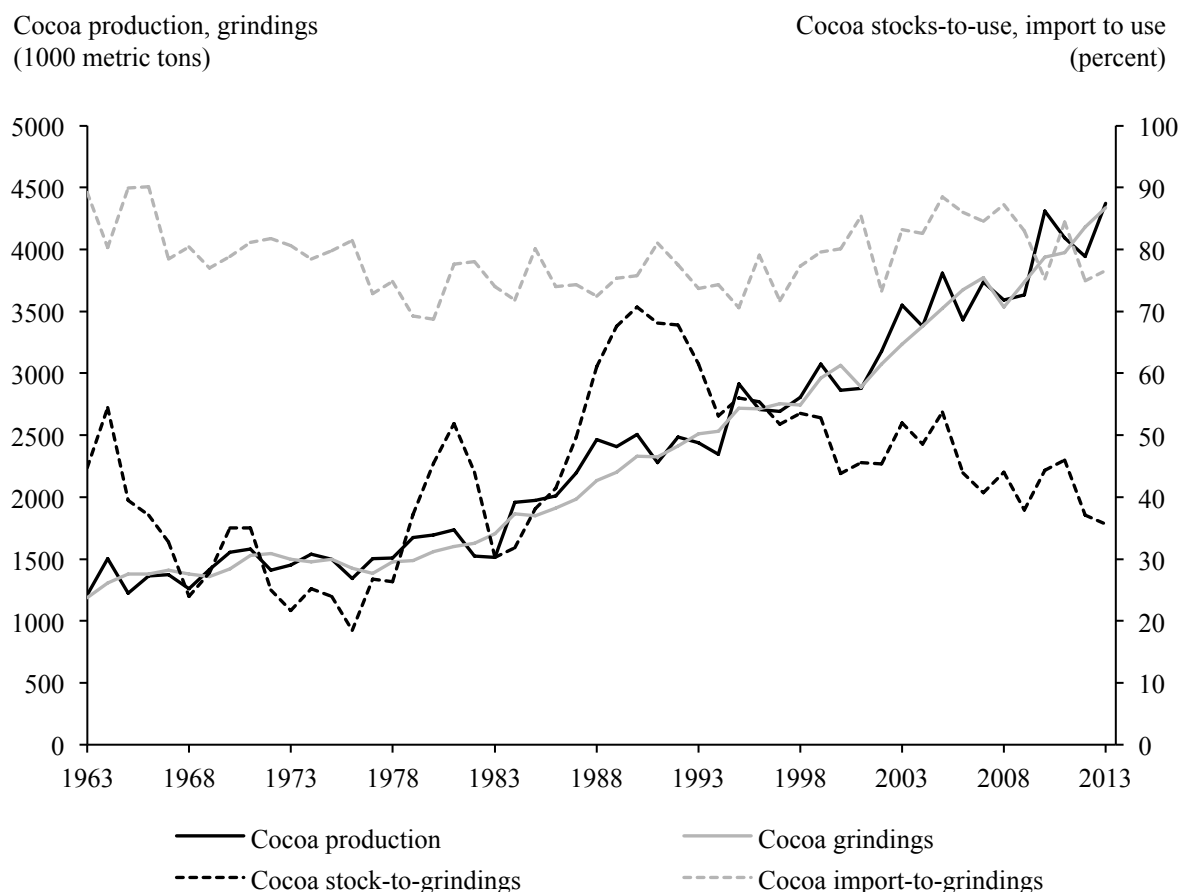
Cocoa production, grindings                                    Cocoa stocks-to-use, import to use
(1000 metric tons)                                                                    (percent)



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

Source: Author's own depiction. We retrieved the data from FAOStat and the 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).

Figure 2 shows the development of the world cocoa price. In the 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 3 064 US dollars/ton, and the real value rose from 1 116 to 2 836 US dollars/ton, which coincided with a drop in the cocoa stocks-to-use ratio – from over 70% to under 40%. However, it can be observed that the world cocoa price is still low compared with the prices dominating 40 years ago, while real chocolate prices have been maintained since the 1970s. The volatility of the world cocoa price, however, increased considerably in the new millennium (ICCO 2012).
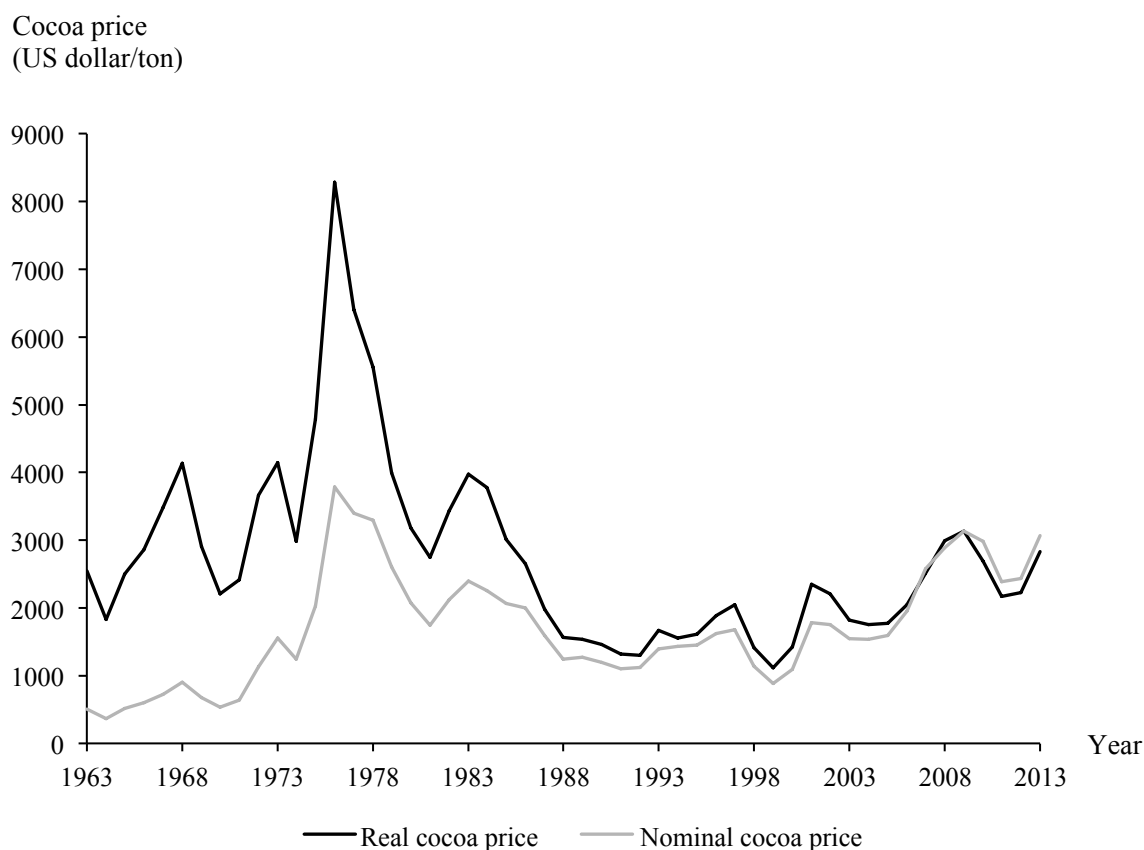
Cocoa price
(US dollar/ton)



**Figure 2: The real and nominal world cocoa price (1963 to 2013)**
Source: Author's own depiction. We retrieved the data from the World Bank GEM

## 2.3 Cocoa price volatility

We assessed the volatility of cocoa price with the coefficient of variation measurements. In the second column of Table 1, the results are compared to the volatility of other commodity prices in the full sample period. We find that, between 1963 and 2013, the volatility of the world cocoa price was 0.50. This value is similar to the volatility of the two other agricultural prices (coffee and wheat). The volatility of the crude oil price (1.02), however, was much higher.

**Table 1: The coefficient of variation of various annual world commodity prices (1963–2013)**

| Commodity | 1963–2013 | 1963–1980 | 1981–1999 | 2000–2013 |
|---|---|---|---|---|
| Cocoa price | 0.50 | 0.78 | 0.26 | 0.35 |
| Coffee price | 0.50 | 0.73 | 0.29 | 0.45 |
| Wheat price | 0.45 | 0.46 | 0.17 | 0.36 |
| Crude oil price | 1.02 | 1.28 | 0.28 | 0.49 |

Source: Author's own calculations. We retrieved the data from the World Bank GEM and the ICCO Quarterly Bulletin of Cocoa Statistics

According to Piot-Lepetit and M'Barek (2011), the stock-to-use ratio does not only affect the commodity price, but also the volatility of the commodity price: when stocks are low, even small changes in supply or demand can have large price effects, but when stocks are high, the opposite is the case. Figure 3 shows that this was also true in the world cocoa market between 1963 and 2013.

Piot-Lepetit and M'Barek (2011) further state that stocks of agricultural commodities cause price volatility cycles: after the stock-to-use ratio reaches a high level, it will stay high until demand has surpassed supply for a long enough time to absorb previous surpluses. With this in mind, we divide our sample into three periods. The first period (1963 to 1980) has the lowest average cocoa stocks-

to-use ratio (33.27%) and ends when this ratio exceeds 50% again. The second period (1981 to 1999) has the highest average stocks-to-use ratio (53.05%) and ends when this ratio dips below 50% again. In the third period (2000 to 2013), the stocks-to-use ratio is again low, with an average of 44.20%. The coefficient of variation is also calculated for these three sub-samples in Table 1. We find that higher volatility coincides with lower average cocoa stock levels.
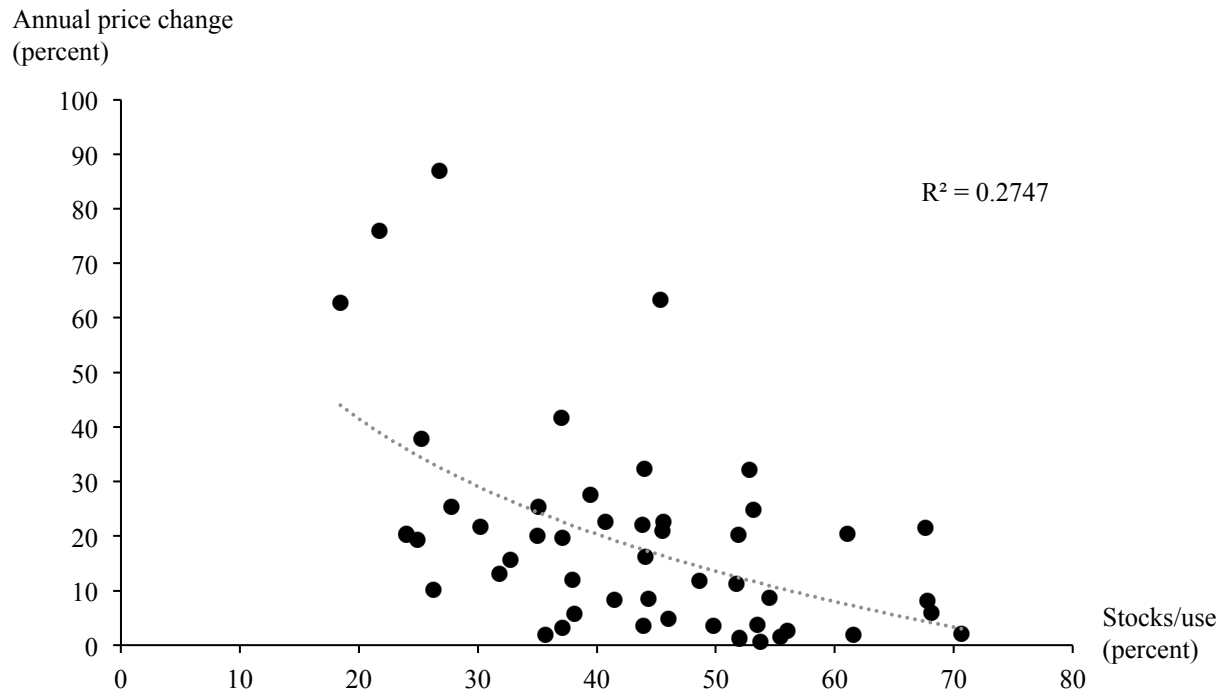


**Figure 3: Scatter plot of the cocoa stocks-to-use ratio and the annual price change (1963 to 2013)**
Source: Author's own calculation and depiction. We retrieved the data from the World Bank GEM and the ICCO Quarterly Bulletin of Cocoa Statistics

Even if the stock-to-use ratio is at a satisfactory level, the absence of transparent market information can amplify volatility in the market (UNCTAD 2011). In agricultural markets like cocoa, although many sources report data on area planted, harvests and demand, organizations lack the capability to aggregate this information in a timely and accurate manner. The biggest problem associated with transparency is poor inventory data. The main reason for inaccurate current inventory information is that a large part of inventories is privately held and this makes data on inventories commercially sensitive (UNCTAD 2011).

## 3. Methodology and literature review

### 3.1 Commodity market models

We used a modified version of the popular commodity market framework of Hallam (1990) and Labys (2006) to devise our own cocoa market model. The framework is composed of three equations. The supply, demand, and inventory sub-models are the following:

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

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

$$I_t = i\,(I_{t-1}, S_t, P_t), \tag{3}$$

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. Lagged commodity inventories, commodity supply, along with commodity price, are used to explain the commodity inventories. The model is closed with the price equilibrator approach (Reynolds *et al.* 2009), rather than the stocks identity, because it usually provides a more accurate simulation of volatile markets.

The framework above is adopted in many price elasticity studies concerning tropical commodities. For example, Adams and Behnman (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 found 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 respectively. 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 to 2002. They estimate two equations, namely 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 respectively. In addition, 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 determined simultaneously (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 the 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.

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. if the number of instrumental variables is larger than the number of endogenous variables. Using the Hansen (1982) test, we evaluate 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, 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 and testing procedures.

We employ the autoregressive distributed lag (ARDL) bounds framework (Pesaran *et al*. 2001) to test for cointegration because it yields unbiased and efficient results in small sample sizes, irrespective of whether the underlying variables are stationary or integrated. If there is evidence that the variables are cointegrated, we estimate the long-term model, otherwise we should take first differences to estimate the short-run model.

## 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 price equilibrator. The cocoa supply, demand, and stock equations are the following:

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

$$Demand_t = \gamma_0 + \gamma_1 CocoaPrice_t + \gamma_2 PalmoilPrice_t + \gamma_3 GDP_t + \gamma_4 Demand_{t-1} + \varepsilon_{t2} \tag{5}$$

$$Stocks_t = \delta_0 + \delta_1 Supply_t + \delta_2 Cocoaprice_t + \delta_3 Stocks_{t-1} + \varepsilon_{t3}. \tag{6}$$

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

$\varepsilon_{tj} \sim \mathcal{N}(0, \sigma_j)$, for all $t = 1 \ldots T$ and $E(\varepsilon_{mj}\varepsilon_{nj}) = 0$ for all $m, n = 1 \ldots T$, $m \neq n$, $j = 1, 2, 3$.        (7)

We specify a dynamic cocoa market model containing both autoregressive and distributed lag components, since cocoa farmers and firms spread their responses over time due to adjustment costs and incomplete and lagged information. This model 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% content of palm oil in chocolate products (Dand 2011). Moreover, the world GDP captures the effect of economic activity on 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 stock equation, based on Reynolds *et al*. (2009), we stipulate the world annual cocoa ending stocks as a function of cocoa supply, cocoa price, and lagged cocoa ending stocks. Because of the four endogenous variables, one more equation is needed in our cocoa market model. Thus, the model is completed with the price equilibrator approach (Reynolds *et al*. 2009): the cocoa price is simulated by finding the equilibrium price, where cocoa supply plus the change in cocoa inventories equals cocoa demand.

## 4.2 Description of data

Our cocoa market model estimates are based on annual global observations covering the years 1963 through 2013. We composed this data set from various sources. The cocoa production and grindings data stem from FAOStat and the ICCO Quarterly Bulletin of Cocoa Statistics. The benchmark commodity prices were drawn from the World Bank's Global Economic Monitor (GEM). The descriptions of the variables, in addition to the units of measurement, are presented in Table 2.

A crucial issue we needed to tackle was 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 decided to use the most widespread definitions of the variables. For example, the world cocoa price was derived from the nearest three trading months on two key cocoa futures markets. We then used the ex-dock New York Arabica/Robusta coffee composite price as the world coffee price. In addition, the 5% bulk CIF Rotterdam palm oil price in Malaysia represents the world palm oil price.

**Table 2: Description of the cocoa market variables**

| Variable | Description |
|---|---|
| Supply | World cocoa bean crop (in 1 000 metric tons) |
| Yield | World cocoa bean yield (in kilograms/hectare) |
| Demand | World cocoa bean grindings (in 1 000 metric tons) |
| Stocks | World cocoa bean ending stocks (in 1 000 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) |

Source: Author's own summary. We retrieved the data from FAOStat, the ICCO Quarterly Bulletin of Cocoa Statistics, the World Bank Pink Sheet, and the World Bank WDI

Another issue with which we were confronted was the selection of the price deflator to form real commodity prices. In this matter, we accepted the recommendation of the World Bank to use its Manufactures Unit Value Index for imported goods for the calculation. Furthermore, we obtained the real world GDP from the World Bank World Development Indicators to capture the effect of economic activity level. Table 3 provides the summary statistics for all the variables in our global cocoa market model before taking natural logarithms.

**Table 3: Summary statistics of the cocoa market variables**

| Variable | Observations | Mean | Standard deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| Supply | 51 | 2 430 | 960 | 1 221 | 4 373 |
| Yield | 51 | 384 | 47 | 266 | 461 |
| Demand | 51 | 2 389 | 947 | 1 305 | 4 335 |
| Stocks | 51 | 1 069 | 535 | 263 | 1 892 |
| Cocoa price | 51 | 2 742 | 1 362 | 1 116 | 8 283 |
| Coffee price | 51 | 3 533 | 1 730 | 1 285 | 11 048 |
| Palm oil price | 51 | 681 | 255 | 290 | 1 518 |
| GDP | 51 | 38 641 | 17 225 | 13 793 | 72 970 |

Source: Author's own calculations. We retrieved the data from FAOStat, the ICCO Quarterly Bulletin of Cocoa Statistics, the World Bank Pink Sheet and the World Bank WDI
Note: We deflated the commodity prices with the MUV Index, and the base year is 2010

We assessed the stationarity of variables with the DF–GLS (Elliott *et al.* 1996) and KPSS (Kwiatkowski *et al.* 1992) tests and, to consider one structural break, with the 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 a structural break. The results of the three unit root tests are mostly consistent. We found that nearly all the non-differenced variables were non-stationary, and all of our variables in the first differenced form were stationary (Table 4). In addition, we tested for cointegration with the ARDL bounds technique (Pesaran *et al.* 2001). Table 5 reports the results: the cocoa market equations represent cointegrating relationships.

**Table 4: Unit root tests of the cocoa market variables**

| Variable | KPSS | | DF–GLS | | Zivot–Andrews | | |
|---|---|---|---|---|---|---|---|
| | Without trend | With trend | Without trend | With trend | Break in constant | 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 |
| $\Delta$Supply | 0.046 | 0.035 | -6.554*** | -6.539*** | -8.276*** | -7.654*** | -8.204*** |
| $\Delta$Yield | 0.167 | 0.038 | -7.686*** | -7.390*** | -9.420*** | -9.006*** | -9.451*** |
| $\Delta$Demand | 0.081 | 0.071 | -4.904*** | -4.910*** | -7.269*** | -7.098*** | -8.226*** |
| $\Delta$Stocks | 0.078 | 0.070 | -4.327*** | -4.296*** | -6.927*** | -6.327*** | -6.878*** |
| $\Delta$Cocoa price | 0.063 | 0.063 | -5.849*** | -6.104*** | -8.216*** | -7.106*** | -8.164*** |
| $\Delta$Coffee price | 0.077 | 0.076 | -4.844*** | -4.832*** | -7.033*** | -6.522*** | -7.008*** |
| $\Delta$Palm oil price | 0.119 | 0.048 | -7.864*** | -8.492*** | -9.589*** | -9.505*** | -9.603*** |
| $\Delta$GDP | 0.872*** | 0.115 | -2.816*** | -4.908*** | -6.464*** | -6.130*** | -6.445*** |

Source: Author's own calculation.
Note: The KPSS tests employ the Quadratic Spectral kernel with automatic bandwidth selection. In the Zivot–Andrews and DF–GLS tests, the Schwarz information criterion selects the lag length with a maximum of 10 lags. *, ** and *** indicate significance at the 10%, 5% and 1% levels respectively.

**Table 5: Cointegration tests of the cocoa market model**

| Model | Without trend | With trend |
|---|---|---|
| Supply equation | 61.19 [3.23, 4.35]*** | 22.24 [4.01, 5.07]*** |
| Demand equation | 12.04 [3.23, 4.35]*** | 134.74 [4.01, 5.07]*** |
| Cocoa stock equation | 10.84 [3.79, 4.85]*** | 9.66 [4.87, 5.85]*** |

Source: Author's own calculation.
Note: The statistics are the F-values of the bounds cointegration technique. The numbers in brackets are the critical lower and upper bounds at the 5% significance level. The tests use the Bartlett kernel with Newey−West automatic bandwidth selection and small-sample adjustments. *, ** and *** indicate significance at the 10%, 5% and 1% levels.

## 5. Results and discussion

### 5.1 Estimator selection

First, we estimated 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 6). 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 6: 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 stock equation | 61.53 | 0.4276 | 0.8220 |

Source: Author's own calculations
Note: The weak instruments test statistics are the F-values of the Kleibergen-Paap method. Furthermore, the overidentifying restrictions and the endogeneity test statistics are the p-values of the Hansen and Eichenbaum 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-Paap F-statistic is smaller than

10.
We re-estimated the cocoa market model with the 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 0.601. 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 7. 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 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 respectively.[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 reveal 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 labour, 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.

## 5.3 Cocoa demand model

The estimated cocoa demand parameters, along with their statistical significances, are shown in Table 8. 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 respectively. 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% cocoa by value (Dand 2011).

Our results furthermore 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).

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

**Table 7: Estimates of the cocoa supply equation**

| Variable | OLS | 2SLS | SUR |
|---|---|---|---|
| Cocoa price$_t$ | 0.069 (0.027)** | 0.254 (0.066)*** | 0.074 (0.040)* |
| Cocoa price$_{t-1}$ | 0.083 (0.060) | −0.130 (0.117) | 0.073 (0.058) |
| Cocoa price$_{t-2}$ | −0.026 (0.050) | 0.084 (0.089) | −0.032 (0.060) |
| Cocoa price$_{t-3}$ | 0.079 (0.038)** | 0.070 (0.044) | 0.087 (0.058) |
| Cocoa price$_{t-4}$ | −0.042 (0.037) | −0.039 (0.075) | −0.051 (0.057) |
| Cocoa price$_{t-5}$ | 0.005 (0.036) | −0.002 (0.065) | 0.010 (0.055) |
| Cocoa price$_{t-6}$ | 0.013 (0.040) | 0.013 (0.060) | 0.012 (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)*** | −0.078 (0.035)** |
| Coffee price$_{t-1}$ | 0.063 (0.068) | 0.119 (0.092) | 0.067 (0.038)* |
| Coffee price$_{t-2}$ | −0.032 (0.052) | −0.055 (0.062) | −0.034 (0.038) |
| Coffee price$_{t-3}$ | −0.071 (0.032)** | −0.088 (0.028)*** | −0.060 (0.037) |
| Coffee price$_{t-4}$ | 0.004 (0.030) | −0.001 (0.032) | 0.003 (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)*** | −0.094 (0.039)** |
| Yield$_t$ | 1.022 (0.118)*** | 1.254 (0.101)*** | 1.022 (0.108)*** |
| Supply$_{t-1}$ | 0.410 (0.056)*** | 0.504 (0.067)*** | 0.430 (0.080)*** |
| Supply$_{t-2}$ | 0.331 (0.067)*** | 0.165 (0.083)* | 0.315 (0.089)*** |
| $R^2$ | 0.991 | 0.987 | 0.991 |

Source: Author's own calculation.
Note: Robust 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: Demand$_{t-1}$ and Stocks$_{t-1}$. *, ** and *** indicate significance at the 10%, 5% and 1% levels respectively.

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 *et al*. 1993).

**Table 8: Estimates of the cocoa demand equation**

| Variable | OLS | 2SLS | SUR |
|---|---|---|---|
| Cocoa price$_t$ | -0.063 (0.020)*** | -0.058 (0.026)** | -0.048 (0.020)** |
| Palm oil price$_t$ | 0.036 (0.010)*** | 0.032 (0.016)** | 0.021 (0.020) |
| GDP$_t$ | 0.132 (0.028)*** | 0.124 (0.024)*** | 0.211 (0.062)*** |
| Demand$_{t-1}$ | 0.817 (0.040)*** | 0.828 (0.036)*** | 0.749 (0.074)*** |
| $R^2$ | 0.992 | 0.992 | 0.992 |

Source: Author's own calculations
Note: Robust 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$_{t-1}$, Cocoa price$_{t-1}$, and Stocks$_{t-1}$. *, ** and *** indicate significance at the 10%, 5% and 1% levels respectively.

## 5.4 Cocoa stock model

The results of the cocoa stock model estimations are displayed in Table 9. They show that the short- and long-term price elasticities of the world cocoa stocks are very inelastic: -0.12 and -0.28 respectively. Furthermore, we find that the long-term supply elasticity of stocks is rather high, with a value around 1.40. In the domestic cocoa studies, this elasticity is usually insignificant, owing to the vast influence of the world cocoa price (Hameed *et al*. 2009).

In addition, the coefficient of the lagged cocoa stocks (0.583) 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 9: Estimates of the cocoa stock equation**

| Variable | OLS | 2SLS | SUR |
|---|---|---|---|
| Supply$_t$ | 0.583 (0.072)*** | 0.511 (0.114)*** | 0.650 (0.151)*** |
| Cocoa price$_t$ | -0.116 (0.070)* | -0.126 (0.153) | -0.107 (0.096) |
| Stocks$_{t-1}$ | 0.583 (0.060)*** | 0.617 (0.160)*** | 0.566 (0.122)*** |
| $R^2$ | 0.944 | 0.943 | 0.946 |

Source: Author's own calculations
Note: Robust 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$_{t-1}$, and Cocoa price$_{t-1}$. *, ** and *** indicate significance at the 10%, 5% and 1% levels respectively.

## 6. Conclusion

The economic and population growth in Africa and Asia have largely boosted the world demand for cocoa and increased volatility in the world cocoa price in this new century. This price volatility makes the millions of African cocoa farmers 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 tested the hypothesis that the price elasticities of the global cocoa supply and demand are low.

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

Our results compare favourably with the 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 respectively. 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 respectively. Moreover, palm oil seems to be a weak cocoa demand substitute. Finally, according to our assessment, the volatility ensuing from the inelastic cocoa supply and demand response is further amplified by the lower average cocoa stock-to-grindings ratio in the new millennium.

Two broad categories of policies can address the increased cocoa price volatility: (1) those that handle volatility itself by attempting to stabilise the cocoa market using supply and price controls, and (2) those that treat the consequences of high volatility while not reducing market signals, for example saving and hedging instruments (Piot-Lepetit & M'Barek 2011).

Various unsuccessful methods have tried to stabilise the cocoa price in the past: planned economies, cocoa stock management, national cocoa marketing boards, and international cocoa agreements (Dand 2011). These experiments caused inefficiencies, led to market failures, and were not likely to win wide support (Sarris & Hallam 2006). In the long run, possible solutions to handle the cocoa price volatility itself might include securing the cocoa supply by fostering innovation, and new cocoa-production technologies.

Treating the consequences of high cocoa price volatility necessitates stabilisation of the cocoa farmers' income. However, farmers in cocoa-producing countries do not have access to effective saving tools and safety nets (Piot-Lepetit & M'Barek 2011). They could also use hedging

instruments like futures, forward and long-term contracts, options, and price swaps to manage cocoa price risks, but these markets are not functioning well in developing countries (Pannel *et al*. 2007). A possible solution for income stabilisation might be the encouragement of crop diversification.

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