An Analysis of Cocoa Market Fundamentals and Price Transmission in the Cocoa Value Chain

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Abstract

After two decades of substantial stagnation, with consequent complaints from producer countries, the international price of cocoa beans has suddenly started to dramatically rise, attracting interest on this commodity, that is a fundamental source of income for millions of smallholders around the world. The present paper offers a broad analysis of the cocoa sector, divided into two main components: an investigation of the cocoa market fundamentals and an assessment of the price transmission inside the cocoa value chain. Both analyses rely on a Vector Error Correction Model, with yearly data (1961-2022) for the evaluation of market fundamentals and monthly data (January 1996-July 2024) for the price transmission investigation. An analysis of structural breaks is conducted in both cases. While the yearly market analysis, that combines prices and quantities, does not present structural breaks except for the price of cocoa beans, all residuals and predicted cointegrated equations of the price transmission analysis show a structural break.

Keywords: Cocoa; VECM; Price Transmission; Structural Change; Market Analysis.

J.E.L. Codes: C22; L66; Q02; Q17.

1 Introduction

The rise in the international price of cocoa beans started in 2023 and continued, with increased intensity, in 2024 has fuelled the interest towards this commodity. Despite not being a basic good with important consequences for food security, cocoa is a key export commodity for several countries, able to generate both revenues and foreign currency that are vital for exporting nations often belonging to the World Bank categories of low or lower-middle income (Franzen and Borgerhoff Mulder, 2007). Furthermore, cocoa is largely produced by smallholders rather than by large farming companies, constituting an important and relatively stable source of income, particularly cash-income, and a valuable collateral asset (Wessel and Quist-Wessel, 2015). Two countries, Ghana and Ivory Coast, are by far the main producers, with a combined share of the world production beyond 50%.

For all these reasons, the cocoa sector has been largely investigated, particularly from a developmental perspective. The effect of training and on/off farm support (Onumah et al., 2014), the contribution to productivity of inputs subsidies (Amfo et al., 2024), or the analysis of technical efficiency among cocoa producers (Amos, 2007) are just few examples of this literature strand. However, cocoa is also an internationally traded commodity, listed both in the ICE Futures U.S. (New York) and in the ICE Futures Europe (London). Thus, cocoa has also been widely studied from a financial point of view.

Some examples are the study of Creti et al. (2013) that analyses the link in volatility between commodities and stock markets, the one of Ameyaw (2024) comparing the response of Ghana's business cycle to price shocks in gold and cocoa or the study of the co-movement of cocoa and coffee prices by Traoré and Badolo (2016). Despite the attention placed on this commodity, there are still several aspects that have been overlooked. Primarily, few studies have tried to investigate the fundamentals of the cocoa market or to look into the price transmission mechanism inside the cocoa value chain (VC). The present paper aims at filling these gaps.

The analysis of the cocoa market and its price dynamics is divided into two parts. One considers yearly data, spanning from 1960 to 2022, while the other relies on monthly data

from January 1996 to July 2024. While the former analysis focuses on the relation between quantities and prices at world level, trying to individuate the fundamentals that influence the cocoa market, the latter delves into the price transmission along the cocoa value chain. This second analysis, for reasons of data availability, is limited to the European market, for which it is possible to retrieve prices of intermediate products such as cocoa paste and cocoa butter together with the price of chocolate products for final consumers. In both cases, a Vector Error Correction Model (VECM) is employed due to the presence of cointegrating vectors. Besides looking at the long term relations among variables (cointegrated vectors) and at the short term responses to shocks (with impulse response functions), the paper further investigates eventual structural breaks. Among the results, it is worth to mention that, while the cocoa market does not seem to present significant structural changes except for the price of cocoa beans, several breaks are individuated in the transmission of prices along the cocoa value chain.

2 Brief Literature Review

As mentioned in the introduction, cocoa is a deeply investigated commodity, both as a tradable good listed in international trade markets and as a cash crop generating important revenues for a significant number of smallholders in several low-income countries. Given the amplitude of the literature dedicated to this commodity, this review focuses solely on the few papers that share the same focus on market fundamentals and analysis of value chain as the present paper.

Among the first investigated topics regarding the formation of cocoa prices, there is the test of the efficient market hypothesis. Mananyi and Struthers (1997) reject such hypothesis for cocoa future prices using a cointegration approach. More focused on the fundamentals determining the international price of cocoa beans is the work of Gilbert (2016), that builds a structural econometric model relating production, price, world GDP and grinding, this last as a proxy of consumption. Based on the model of Weymar (1968), that relies on the supply of storage theory and rejects the efficient market hypothesis, Gilbert (2016) extends

the time span of the analysis of Weymar confirming several of the previous findings and individuating long lasting effects of both production and demand shocks.

Other focal points that have attracted the attention of researchers are the distribution of power inside the cocoa value chain and the price transmission between producers, international traders and final consumers. With 2 countries controlling more than half of the world production, the apparent lack of oligopolistic rents always puzzled researchers. Staritz et al. (2023) focus on this aspect but mostly through a descriptive analysis, while Bonjean and Brun (2008) evaluates the Prebisch-Singer hypothesis under the lens of a power game between cocoa producer countries and the few multinational companies that control the cocoa/chocolate market. Specifically, they develop a microeconomic model describing price formation in case of monopoly/oligopoly(monopsony/oligopsony) and test it by looking at cointegration (or lack of it) between prices at different stages of the cocoa VC. They also look at potential breaks in the price formation mechanism finding that, till 1985, Ivory Coast seems to enjoy a monopolistic status, but from the 1990s there is a power shift in favour of cocoa traders/chocolate producers.

Still devoted to the analysis of global value chain (GVC), but extending the analysis to both cocoa and coffee, whose prices appear interlinked, is the work of Gilbert (2008). Similarly to Bonjean and Brun (2008), three different prices are taken into consideration: producer prices (what received by farmers in producing countries), the fob (free on board) international price of cocoa beans and the average retail price of a chocolate tablet in selected European markets[1]. Results, however, are strongly different, with Gilbert (2008) rejecting the hypothesis of a deterioration of the terms of trade of producer countries due to a concentration of traders/chocolate makers, and rather attributing this deterioration to increases in transformation costs, such as wages growth in industrialized countries.

The present analysis has some significant departures from previous studies. In fact, it combines an examination of cocoa market fundamentals and price transmission inside the cocoa VC. For the former analysis, the international price of cocoa beans is related to the

[1]U.K in Gilbert (2008) and France in Bonjean and Brun (2008).

globally produced quantity of cocoa and to the stock-to-grind ratio, adding fertilizers and food price indexes, with the former being a control for production costs. For the latter analysis, instead, the international price of cocoa beans and the unit price of cocoa paste, butter and chocolate products inside the European market are considered. Thus, differently from Gilbert (2016, 2024) and Bonjean and Brun (2008), the present paper does not consider producers prices, unavailable at monthly level for the considered time span, but it adds two intermediate goods such as cocoa paste and butter that help to better understand how the final retail price of chocolate is formed.

3 Data Description

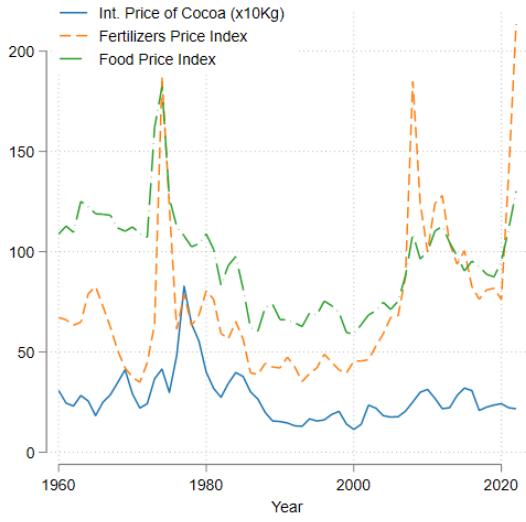
Starting with the yearly analysis of cocoa market fundamentals at world level, the relation between five time series is investigated: the world price of cocoa, the total quantity of produced cocoa, the ratio of the global stock of cocoa over the global ground quantity and, finally, two price indexes of commodities potentially impactful for the cocoa market, namely fertilizers and food. The time span ranges from 1961 to 2022. The world price and produced quantity of cocoa are obtained from the International Cocoa Organization (ICCO). The former, in dollars per tonne, has been converted into dollars per kilogram and made real using the U.S. consumer price index (CPI) as a proxy for the world inflation. It has to be noted that the ICCO price of cocoa is the average of the quotations of the ICE (International Exchange) Futures Europe and ICE Futures U.S markets, with its yearly value being a weighted average of daily quotations. The global stock and the total quantity of ground cocoa per year are also obtained from ICCO, with their ratio being considered as an indicator of price expectations and often analysed when investigating the cocoa market: e.g. Afoakwa (2014) and Gilbert (2016). The price index of fertilizers, a typical input in cocoa and, more broadly, in agricultural production, is obtained by the World Bank Commodity Markets "Pink Sheet", together with the food price index. These are built by considering the weighted average of the international prices of different specific items, such as Urea and Potassium Chloride for fertilizers. The Pink Sheet itself reports

the detailed methodology for their construction and the source for the prices of the items included in the index. It has to be noted that the food price index includes several agricultural commodities such as maize, wheat and soybean, together with other food groups such as chicken and beef meat. It excludes cocoa, coffee and tea, that are instead included in the agricultural products price index. Despite the small share of the cocoa price on the index of agricultural products prices, the food price index has been preferred to avoid endogeneity issues.

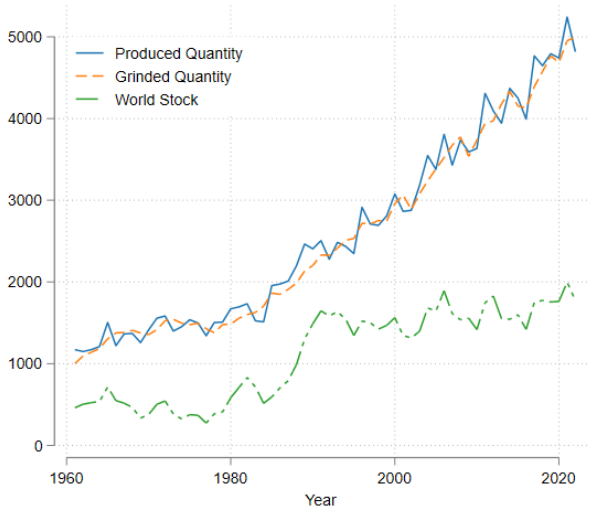
Figure 1 shows all the mentioned series divided in three graphs. The first (a) shows the main quantities, namely the globally produced and ground quantities of cocoa together with world stocks. The long term trend of cocoa production is clearly a steady rise, closely mirrored by the ground quantity. Stocks, instead, have seen a rapid increase in the first half of the eighties, preceded and followed by periods of oscillation around a rather stable average. The second graph (b) compares the price quantities, namely the international price of cocoa and the fertilizers and food price indexes. These last two are strongly linked until, approximately, 2006-07, when a sharp and relatively short spike of commodities prices, particularly energy goods, has anticipated several years of global economic crisis. Compared to the oil price shock of 1973-74, where both fertilizers and food prices have been similarly impacted, in 2006-07, the reaction of the latter has been weaker. This trend seems confirmed in 2022, after the Russian invasion of Ukraine has caused another sharp increase of commodity prices, with the rise of fertilizers prices being much more pronounced than the one food commodities. The price of cocoa seems to follow a pattern similar to the two price indexes, although with one or two years of delay. This is true until the first years of the 2000s, after which the fluctuations of the cocoa price still follow the ones of the two indexes, but with a much lower magnitude. The last graph (c) shows the international price of cocoa in relation with the stock-to-grind ratio. The two series appear to have opposite paths, with this being not surprising since high(low) cocoa prices may signal an excess(defect) of demand compared to production that may be compensated by reducing(increasing) stocks.

Shifting to the second topic, the analysis of price transmission inside the cocoa value

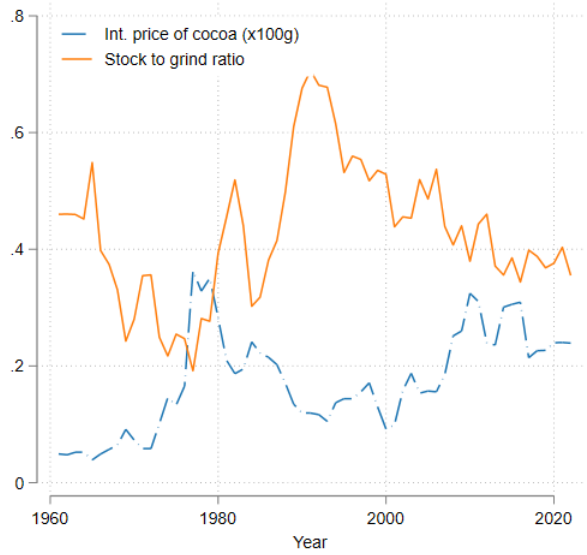
Figure 1: Variables for the Cocoa Market Analysis



(a) Cocoa Quantities (Tons x $1000^{(}-1)$)



(b) Cocoa Price and Price Indexes



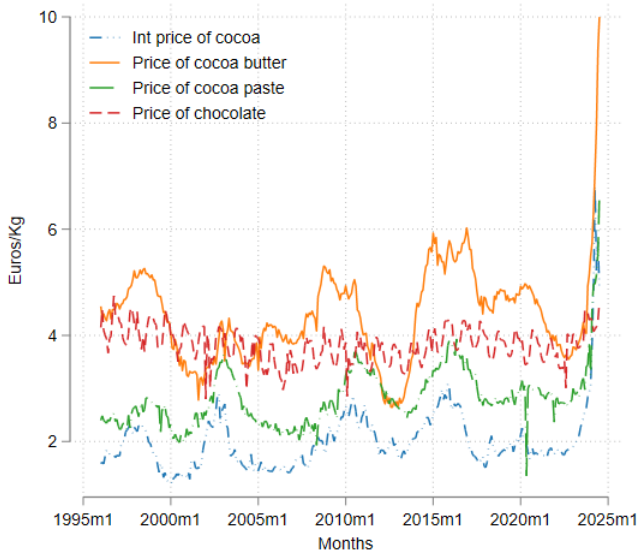
(c) Cocoa Price and Stock to Grind Ratio

chain, we have four variables of interest: the international price of cocoa, the price of cocoa paste (or liquor) and of cocoa butter, and, finally, the price of chocolate products[2]. While

[2]In particular, the Eurostat codes of the products are: 1803 = Cocoa paste, whether or not defatted; 1804 = Cocoa butter, fat and oil; 1806 = Chocolate and other food preparations containing cocoa.

the first series is basically the ICCO world price of cocoa previously described, but with a different time aggregation, the other prices have been obtained from Eurostat, by dividing the total traded value by the total traded quantity of each commodity inside the European Union (unit prices). Since these prices are in euros, the international price of cocoa has also been converted to the same currency. Furthermore, the EU consumer price index (CPI) has been used to make all prices constant, with January 2015 as the base month. The time span ranges from January 1996 to July 2024.

Figure 2: Price of Products at Different Stages of the Cocoa Value Chain



Compared to other studies that have included in their value chain (VC) analysis the producer price paid to farmers in cocoa producing countries (e.g. Bensch et al. (2023); Bonjean and Brun (2008); Gilbert (2008)), we do not have this data both for its unavailability at monthly and at global level. The mentioned papers, in fact, focus on a specific cocoa producer country (e.g. Ivory Coast) or on a small sample of them, relying on yearly data. The other important caveat to keep in mind is related to the other end of the value chain, namely to chocolate products. Bonjean and Brun (2008) use the average price of a chocolate bar to define the consumers' price of chocolate. Unfortunately, Eurostat do not offer such

information and the category of chocolate products is much broader, including, according to the Eurostat definition, "chocolate and other food preparations containing cocoa". This likely implies a far higher noise when considering this last step of the cocoa VC since the price of many other products (e.g. sugar, milk, nuts, cream, etc.) concur to form the price of chocolate products, with cocoa not being the sole determinant.

Figure 2 shows the series of the four prices that appear to co-move and to respond similarly to shocks, with the price of chocolate products being the exception. This is well visible looking at the periods 2002-04, 2009-12 and 2014-17, where all prices had a sharp increase followed by a decline. As just mentioned, the exception is the price of chocolate products, that seem to follow cyclical oscillations. In general, the international price of cocoa, or else, the price of cocoa beans, is at the bottom, followed by the price of cocoa paste/liquor. The price of chocolate products, the last item in the value chain, occupies an intermediate position between the price of cocoa paste and cocoa butter, with this last being the highest value. Cocoa butter is obtained by further processing cocoa paste. In the preparation of chocolate, a certain amount of cocoa butter is added back to cocoa paste in order to obtain the final product. Theoretically, therefore, the price of pure dark chocolate would be mainly[3] determined by the weighted average of the price of cocoa butter and cocoa paste, with the weights being given by their relative proportions in the final product. There are periods, generally short, where this order is not strictly respected. In 2001-02 and 2012-13, for example, the price of cocoa butter has been lower than the one of chocolate products. However, these are exceptions, while the mentioned order of prices is maintained for the most part of the analysed period.

Seasonality is a potential source of bias in time series analysis. This is particularly true when dealing with prices and quantities that are related to agricultural commodities, naturally affected by seasonality due to cropping calendars. In order to individuate seasonality patterns, for each of the four considered price series, it has been computed the percentage difference of each monthly price with the yearly average price. Such monthly

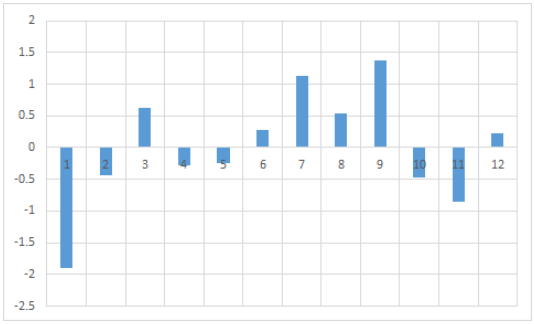
[3]The price of other components, such as sugar, will also concur to the formation of the final price of chocolate.

percentage differences have been finally averaged over all years in order to obtain Figure 3. In the absence of seasonality, the final average should tend to zero, since differences in different years should tend to cancel out. From Figure 3, however, we can observe that this is not the case, particularly for the price of chocolate products, where the monthly price in the late spring-early summer are between 5% to 7% lower than the year average, while late autumn-early winter prices are between 6% to 8% higher. A similar pattern seems to occur to the price of cocoa paste and butter, but the amplitude is far less marked, with the average differences being almost always lower than 2%. Interestingly, the price of cocoa beans, the product theoretically more subject to agricultural seasonality, seems to be the one less affected by it. This may be explained by the fact that dried cocoa beans are not so perishable, being possible to store them for up to twelve months (Dano et al., 2013). Seasonality, therefore, appears mainly driven by the demand side, with the consumption of chocolate products increasing in cold months and decreasing in hotter ones. Moskowitz and Beckley (2009), in fact, have individuated mild seasonality for the consumption of chocolate candies.

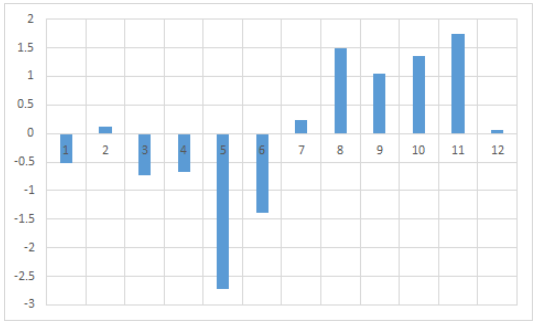
4 Methodology

The first step for the analysis of both the cocoa market and the price transmission along the cocoa value chain is the investigation of each single variable to assess their stationarity or lack of it. After having individuated the optimal number of lags looking at different criteria (Akaike's Final Prediction Error (FPE), Akaike Information Criterion (AIC), Hannan-Quinn Information Criterion (HQIC) and Schwarz's Bayesian Information Criterion (SBIC)), an Augmented Dickey-Fuller (ADF) and a Phillips-Perron (PP) tests for unit root have been conducted. The results are reported in Table 1, with (a) showing the MacKinnon Approximate P-values for the yearly variables and (b) for the monthly prices. The tests have been conducted with drift, with time trend and with neither of them (only ADF). The H0, namely the presence of a unit root, is rejected at the 5% level of confidence for all the yearly cocoa related variables in one of the three configurations (none, drift and trend)

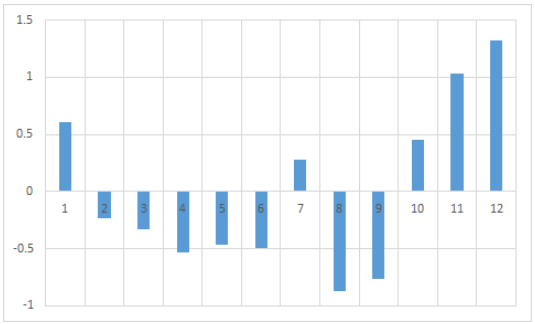
Figure 3: Average Monthly Deviations from the Year Average Price of Different Products along the Cocoa Value Chain



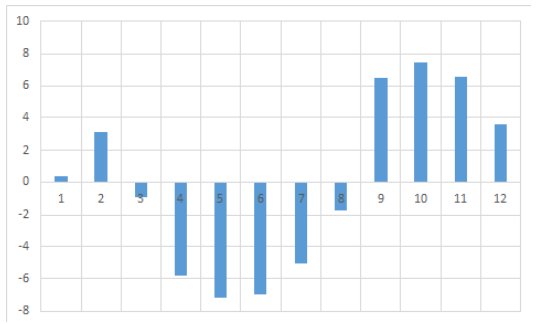
(a) Int. Price of Cocoa



(b) Price of Cocoa Paste



(c) Price of Cocoa Butter



(d) Price of Chocolate Prod.

when the ADF test is considered. The same result, but with a significance decreased at the 10% level, is obtained for the price indexes (food and fertilizers). However, the results of the PP test are rather different with the null hypothesis being never rejected at even the 10% level except for the quantity of cocoa. Only this last variable finds an agreement between the ADF and PP tests, both indicating it as trend stationary. However, a Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test for trend stationarity has been further conducted on this series, rejecting at the 5% level of confidence the null hypothesis of trend stationarity.

Similar results are obtained for the monthly price variables, with the ADF test having the null rejected at the 5% level of confidence (with drift) for all of the four considered series, while the random walk hypothesis is not rejected by the PP test. There are, however, two notable exceptions. One is the price of chocolate, for which both the ADF and PP tests agree in rejecting the unit root hypothesis when a drift is present. Furthermore, the PP

Table 1: Augmented Dickey-Fuller Test for Yearly and Monthly Variables with MacKinnon Approximate P-values

Augmented Dickey-Fuller and Phillips-Perron Unit Root Tests (H0: Unit Root)						
	With no drift nor trend	***With drift***		***With trend***		***Lags N.***
	ADF	**ADF**	**PP**	**ADF**	**PP**	
Int P. of cocoa	0.234	0.019**	0.282	0.535	0.519	3
Cocoa Q	0.907	0.339	0.885	0.019**	0.001**	1
Stk-Gr ratio	0.198	0.015**	0.198	0.443	0.449	1
Food Index	0.519	0.066*	0.504	0.950	0.909	4
Fertilizers Index	0.608	0.092*	0.387	0.670	0.499	3

(a)

Augmented Dickey-Fuller and Phillips-Perron Unit Root Tests (H0: Unit Root)						
	With no drift nor trend	***With drift***		***With trend***		***Lags N.***
	ADF	***ADF***	***PP***	***ADF***	***PP***	
Int. price of cocoa	0.024**	0.001***	0.356	0.020**	0.433	12
Price of cocoa paste	0.514	0.062*	0.156	0.284	0.024**	9
Price of cocoa butter	0.088*	0.004***	0.750	0.151	0.890	7
Price of chocolate	0.304	0.025**	0.000***	0.773	0.000***	14

(b)

test rejects the null for both the price of chocolate and the one of cocoa paste in presence of a trend. For the former price, however, the KPSS test rejects the stationarity hypothesis at the 5% level. Considering that the PP test is generally more performant than the ADF test (Afriyie et al., 2020), almost all series appears to be non-stationary, even more so when further considering the results of the KPSS test. The price of chocolate is the exception, since stationarity with drift cannot be excluded. Note that, for all variables, the ADF and PP tests on their first differences rejects the random walk hypothesis at the 1% or 5% level of confidence in all three cases (with drift, with trend and with neither of them).

Once analysed all variables singularly, the presence of cointegration is investigated for the two subset of variables pertaining to the cocoa market fundamentals and price transmission

analyses. After having checked again the optimal number of lags for both sets of variables, individuating five lags for the yearly variables and four for the monthly ones, the Johansen (1991) cointegration test has been conducted. From Table 2, showing the results of the test for the cocoa market (a) and for the price transmission (b) analysis, it is possible to see that there are two cointegrating equations in both cases.

Table 2: Results of Johansen Cointegration Test

Johansen Cointegration Test (5 lags)				
Max Rank	***Param***	***Eigenvalues***	***Trace Stat.***	***5% Critical value***
0	110	-	101.413	77.74
1	119	0.53853	57.3324	54.64
2	126	0.36964	31.0287*	34.55
3	131	0.23626	15.6657	18.17
4	134	0.19681	3.1736	3.74
5	135	0.05416		

(a)

Johansen Cointegration Test (4 lags)				
Max Rank	***Param***	***Eigenvalues***	***Trace Stat.***	***5% Critical value***
0	52	-	109.1688	47.21
1	59	0.15917	50.3966	29.68
2	64	0.117	8.2159*	15.41
3	67	0.01258	3.9238	3.76
4	68	0.01151	-	-

(b)

4.1 The Model

Remembering that a group of variables is cointegrated if each of them is an I(1) process but a linear combination of them is an I(0) process, the Johansen cointegration tests results shown in Table 2 confirm the existence of two such vectors both for the cocoa market and

for the price transmission variables. This calls for the use of a VECM model, that can be defined as a special type of VAR model. Starting with this last, we have:

$$\boldsymbol{y}_t = \boldsymbol{v} + \boldsymbol{A}_1 y_{t-1} + \boldsymbol{A}_2 \boldsymbol{y}_{t-2} + ... + \boldsymbol{A}_p \boldsymbol{y}_{t-p} + \boldsymbol{\epsilon}_t; \tag{1}$$

where y_t is a K dimensional vector of variables, v a K dimensional vector of parameters, $A_1 - A_p$ are $K \times K$ matrices of parameters and ϵ_t is a K dimensional vector of disturbances. With this being the definition of a VAR(p) model, it can always be written in the form of a VECM model:

$$\Delta \boldsymbol{y}_t = \boldsymbol{v} + \boldsymbol{\Pi} \boldsymbol{y}_{t-1} + \sum_{i=1}^{p-1} \boldsymbol{\Gamma}_i \Delta \boldsymbol{y}_{t-i} + \boldsymbol{\epsilon}_t; \tag{2}$$

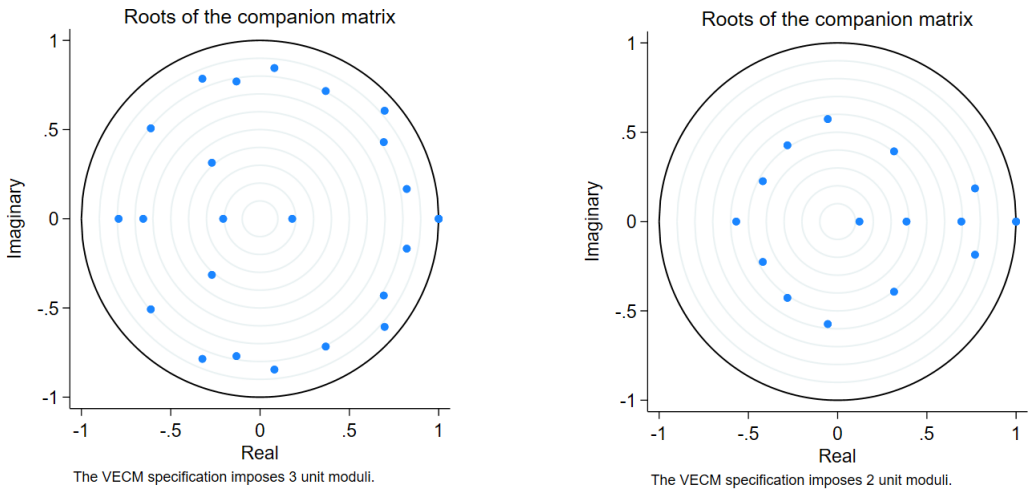
with $\boldsymbol{\Pi} = \sum_{j=1}^{p} \boldsymbol{A}_j - \boldsymbol{I}_k$ and $\boldsymbol{\Gamma}_i = -\sum_{j=i+1}^{p} \boldsymbol{A}_j$. Furthermore, $\boldsymbol{v}$ and $\boldsymbol{\epsilon}_t$ are exactly as in (1), and we have $\Delta \boldsymbol{y}_t$ instead of $\boldsymbol{y}_t$ since the variables in (1) are supposed to be I(0) while in (2) they are I(1), therefore first differences are used. Once considering this, the only difference between the two models stays in $\boldsymbol{\Pi} \boldsymbol{y}_{t-1}$, with $\boldsymbol{\Pi}$ being a matrix of rank r, with r being the number of cointegrating vectors and $0 < r < K$. In presence of cointegration, therefore, a VAR model would be misspecified since it omits the cointegration term $\boldsymbol{\Pi} \boldsymbol{y}_{t-1}$.

4.2 Models Diagnostics

Before presenting the results of the VECM models and discussing them, some diagnostic analyses are presented. Explosive behaviours are generally a concern in both VAR and VECM regressions, being a sign of misspecification. In order to evaluate the stability of a model, it is common to check that the moduli of the eigenvalues are strictly less than unity, excluding the $K - r$ unit moduli that are imposed by VECM. Figure 4 shows the eigenvalues of the estimated models, from which it is possible to see that all of them lie inside the unit circle, thus excluding explosive behaviours.

Another important sign of model misspecification is the presence of serial correlation

Figure 4: Moduli of the Eigenvalues of the VECM Regressions



(a) Cocoa Market (b) Price Transmission

among the residuals. Table 3 reports the p-values of the Lagrange Multiplier Test, having for null hypothesis the absence of serial correlation among residuals. In no one of the VECM estimations, namely the cocoa market and the price transmission analyses, the null hypothesis is rejected at the 5% level. Serial correlation, therefore, does not seem to be an issue.

Table 3: P–values of the Lagrange Multiplier Test for Serial Correlation

Lags	**Market Analysis**	**Price Transmission**
1	0.6781	0.3770
2	0.9647	0.3948
3	0.3926	0.2519
4	0.8258	0.4029
5	0.9597	0.1001
6	0.4542	0.7352
7	0.6913	0.3799
8	0.0652*	0.6634
9	0.9206	0.5365
10	0.3285	0.0647*

Significance levels: *=10%, **=5%, ***=1%

The last test is dedicated to evaluate the normality of the residuals. Table 4 reports the p–values of the Jarque–Bera Normality Test for each equation and for both VECM estimations. The null hypothesis of normally distributed errors is always rejected at the 1% significance level in the price transmission analysis. Figure A1 in the Appendix shows the frequency distribution of the residuals from the price transmission analysis. From the plots, it is possible to observe that the departure of the distribution of residuals from normality is not so dramatic. For the cocoa market analysis, instead, only the residuals of the stock–to–grind equation are not normally distributed, while the null fails to be rejected in all other cases.

Table 4: P–values of the Jarque–Bera Normality Test

Cocoa Market		**Price Transmission**	
Dependent	**P-values**	**Dependent**	**P-values**
Int P. of cocoa	0.8767	***Int P. of cocoa***	0.0000***
Cocoa Q	0.7885	***Price of cocoa paste***	0.0000***
Stk-Gr ratio	0.0025***	***Price of cocoa butter***	0.0000***
Food Index	0.5309	***Price of chocolate***	0.0000***
Fertilizers Index	0.9542		
All	0.1690	***All***	0.0000***

Significance levels: *=10%, **=5%, ***=1%

5 Results and Discussion

Table 5 shows the estimated cointegrating vectors for both the cocoa market (a) and for the price transmission (b) analysis. These reflect the long-term relation between the analysed variables. Note that, for both analyses, a trend has been added, with this being often significant at different levels of confidence. If we take the first cointegrating vector of Table 5(a), we can see that the long term relation is as follows:

$$Int\ P.\ Cocoa + 0 \times Cocoa\ Q - 3.68 \times StkGr - 1.58 \times Food\ Ind. - 1.87 \times Fert\ Ind. + 0.003 \times t + 4.07 = 0,$$

or else:

$$Int\ P.\ Cocoa = -4.07 + 3.68 \times StkGr + 1.58 \times Food\ Ind. + 1.87 \times Fert\ Ind. - 0.003 \times t.$$

This implies that the international price of cocoa, in the long term, is driven up by increasing levels of stock-to-grind ratio and by increases in the food and fertilizers price indexes, while it is declining over time. However, only the coefficients of stock-to-grind ratio and fertilizers prices are statistically significant at conventional levels. If the positive relation with the price of fertilizers is as expected, it is less so the one with stock-to-grind ratio. By looking at the second cointegrating vector, where the produced quantity of cocoa is the normalized element, it is possible to see that it has a long-term significant relation with the stock-to-grind ratio (negative) and with the time trend (positive). Remember that signs should be inverted when considering the relation with a particular variable. Both relations are as expected since growing stocks will likely cause a decline in future production while the positive time trend can be easily explained by looking at Figure A2 in the Appendix, that shows the global acreage dedicated to cocoa production, the total produced quantity and the per hectare yields over time. Yields have grown over time, although they have started to stagnate since the late nineties. The acreage dedicated to cocoa, however, has been steadily increasing, thus the total produced quantity has always been rising over time.

Note that, in neither of the two vectors, the food price index is significant, implying that, in the long-run, the dynamics of the cocoa market are independent from the ones of the food sector as a whole. This is not surprising by considering the special nature of chocolate as a comfort good rather than as a proper food. The significance of the fertilizer price index in influencing cocoa price but not quantity may imply that farmers do not respond to increases in fertilizers prices by reducing their use, but actually increasing the price of their produce.

Looking at Table 5(b), the relation among all variables is statistically stronger. Considering that they are all prices of products along the cocoa VC, the high statistical significance

Table 5: Coefficients of the Estimated Cointegrating Vectors

Variables	Cointegrating equation 1	P-values	Cointegrating equation 2	P-values
Int P. of cocoa	1	-	0	-
Cocoa Q	0	-	1	-
Stk-Gr ratio	-3.6787***	0.0010	0.3095**	0.0290
Food Index	-1.5777	0.4220	0.4078	0.1100
Fert. Index	-1.8737**	0.0500	-0.0251	0.8400
Trend	0.0031	0.8680	-0.0243***	0.0000
Const.	4.0664	-	-8.5007	-

(a)

	Cointegrating Vector 1		Cointegrating Vector 2		Cointegrating Vector 1		Cointegrating Vector 2	
Variables	Coefficients	P-value	Coefficients	P-value	Coefficients	P-value	Coefficients	P-value
Price of chocolate	1	-	0	-	-6.2640***	0.000	0.4727**	0.040
Int P. of cocoa	0	-	1	-	0.9272***	0.005	-0.9803***	0.000
P.of cocoa butter	-0.1719***	0.001	-0.0829	0.295	1	-	0	-
P. of cocoa paste	-0.1626**	0.017	-1.0986***	0.000	0	-	1	-
Trend	0.0003***	0.005	0.0004***	0.005	-0.0015**	0.031	-0.0003*	0.073
Const	-0.8884	-	0.4742	-	6.0046	-	-0.8848	-

(b)

Significance levels: *=10%, **=5%, ***=1%

is not surprising. From Table 5, we can observe that the price of chocolate products in the European market is positively influenced by the prices of cocoa paste and butter. Since these lasts are immediate predecessors of chocolate in the cocoa VC, it is very reasonable that they are positively linked with the price of chocolate. Further note the positive coefficient of the trend, implying, after inverting the sign, a declining price of chocolate products over time. The second cointegrating vector, having the international price of cocoa beans as normalization element, shows a positive and significant relation with the price of cocoa paste and a declining trend over time. Contrary to the yearly investigation, where the negative time trend of the international price of cocoa is not significant, here it is at the 1% level. Table 5(b) further shows the same cointegrating vectors, but with different prices as normalization factors, namely the price of cocoa butter and paste. Both exhibit an increase along time (positive trend, once the sign is reversed), implying that eventual technical progresses have been more than compensated by increases in production costs, as observed in

Gilbert (2016). The sign of the coefficients of the other two prices at the extremes of the value chain are instead opposite. The price of butter is positively correlated with the one of chocolate and negatively with the price of cocoa beans, while the opposite holds for the price of cocoa paste.

5.1 Short–term Dynamics: Cocoa Market Analysis

Once examined the long term relations among the variables of both the cocoa market and the price transmission analysis, we now revert to the short term dynamics. Table 6 shows the estimated coefficients for the cocoa market analysis, namely for the error correction terms and for the first four differenced lags of each variable. Only two error correction coefficients are significant, namely the coefficient of the fertilizers price index for the first equation, and the total quantity of produced cocoa for the second. Both have the expected sign, opposite to the sign of their respective element in the appropriate cointegrating vector.

The cocoa related variables, namely the international price of cocoa, its world produced quantity and the stock–to–grind ratio, impact all other variables mainly through their last two lags, while the first two are rarely significant. Another interesting fact to note is that the fertilizers price index is scarcely impacted by short term shocks, except for a positive response to the first lag of the food price index. This is reasonable since cocoa represents a small portion of agricultural production, thus its related variables do not exert a strong influence on fertilizers prices, differently from the food price index, that is more indicative of the whole agricultural sector. However, the same food price index is impacted by all the cocoa related variables, while it is strangely insensitive to shocks in fertilizers prices.

When the cocoa related variables are the dependent, the sign of the explanatory coefficients are generally as expected. An exceptions is the positive coefficient of the cocoa price in the equation having the stock-to-grind as dependent. A high price should signal an excess of demand, thus causing a reduction in the stock–to–grind ratio. The significant lag, however, is the third, possibly implying that the positive effect on the stock–to–grind ratio could be due to the replenishing of stocks after a first period of depletion. The pro-

duced quantity of cocoa is positively impacted by shocks in the price of cocoa and in the food price index, with this last having a more immediate effect, and negatively by shocks in the fertilizer price index. Thus, in the short term, farmers seem to react to fertilizer prices increase by lowering the applied quantities. Finally, the international price of cocoa is negatively impacted by itself, by the produced quantity of cocoa and by the food price index, but the impact becomes positive when the fertilizer price index is considered.

Table 6: Estimates of the VECM Regression for the Cocoa Market Analysis

	Int P. of cocoa		**Cocoa Q**		**Stk-Gr ratio**		**Food Index**		**Fertilizers Index**	
	Coeff.	***P-values***	***Coeff.***	***P-values***	***Coeff.***	***P-values***	***Coeff.***	***P-values***	***Coeff.***	***P-values***
ECT_eq1	0.0374	0.6600	-0.0123	0.6450	0.0574	0.3240	0.0049	0.9170	0.2409**	0.0130
ECT_eq2	1.1798	0.1220	-0.6629***	0.0060	-0.4709	0.3680	0.2886	0.4980	1.4176	0.1030
					International price of cocoa					
Δ*Lag 1*	0.2265	0.3970	-0.1119	0.1830	0.1362	0.4570	-0.0677	0.6500	-0.3814	0.2110
Δ*Lag 2*	0.1586	0.5390	-0.0496	0.5410	-0.1664	0.3470	0.1631	0.2570	0.1322	0.6530
Δ*Lag 3*	-0.6165**	0.0110	0.1324*	0.0810	0.4314***	0.0090	-0.3686***	0.0060	-0.3550	0.1970
Δ*Lag 4*	0.2729	0.2050	-0.0647	0.3390	-0.0577	0.6960	-0.0063	0.9580	-0.1819	0.4590
					World produced quantity of cocoa					
Δ*Lag 1*	-0.1644	0.8280	-0.1198	0.6160	0.6619	0.2030	-0.4197	0.3210	-1.1417	0.1870
Δ*Lag 2*	-0.2489	0.7470	0.0431	0.8590	0.4131	0.4340	-0.3689	0.3900	-0.0307	0.9720
Δ*Lag 3*	-1.4326**	0.0330	0.5273**	0.0120	1.1968***	0.0090	-0.6449*	0.0850	-0.8202	0.2830
Δ*Lag 4*	-0.5403	0.2820	0.3312**	0.0360	0.3956	0.2510	0.1356	0.6280	-0.0335	0.9530
					Stock–to–grind ratio					
Δ*Lag 1*	-0.4481	0.2420	-0.0637	0.5970	0.1582	0.5470	-0.0295	0.8900	0.1021	0.8150
Δ*Lag 2*	0.1195	0.7430	-0.0205	0.8580	-0.0516	0.8360	0.4493**	0.0270	0.3360	0.4190
Δ*Lag 3*	-0.1339	0.7090	-0.0712	0.5270	0.0641	0.7940	-0.1369	0.4930	0.2743	0.5020
Δ*Lag 4*	0.0208	0.9520	-0.0972	0.3700	0.1157	0.6240	-0.5019***	0.0090	-0.1488	0.7050
					Food price index					
Δ*Lag 1*	-0.1675	0.7030	0.3139**	0.0230	-0.0425	0.8880	0.2078	0.3970	1.6477***	0.0010
Δ*Lag 2*	-1.4147***	0.0030	0.7156***	0.0000	0.9906***	0.0030	-0.5336**	0.0480	-0.4121	0.4550
Δ*Lag 3*	-0.7151	0.1750	0.2331	0.1600	-0.1454	0.6870	0.1166	0.6910	0.6360	0.2900
Δ*Lag 4*	-0.5525	0.2950	0.1018	0.5400	0.1863	0.6070	-0.1931	0.5120	0.0077	0.9900
					Fertilizers price index					
Δ*Lag 1*	0.0187	0.9220	-0.1369**	0.0230	-0.0104	0.9370	0.0469	0.6610	0.0590	0.7870
Δ*Lag 2*	0.5601***	0.0080	-0.1738***	0.0090	-0.1385	0.3400	0.0750	0.5250	-0.0472	0.8450
Δ*Lag 3*	0.5731**	0.0100	-0.1070	0.1270	-0.0644	0.6740	-0.0037	0.9770	0.2526	0.3210
Δ*Lag 4*	-0.0563	0.7850	0.0147	0.8200	0.0506	0.7200	-0.0215	0.8520	0.0503	0.8300
Const.	-0.0055	0.9320	0.0553***	0.0060	-0.0409	0.3540	0.0188	0.6000	0.0130	0.8590

Significance levels: *=10%, **=5%, ***=1%

Short term effects are better investigated through impulse response functions (IRFs)

that offer a more clear picture of the impact of a shock (a one standard deviation) in the value of a variable on the dependent. Figure A3, in the Appendix, shows the IRFs of each variable on all other variables for the cocoa market analysis. From the figure, it is possible to see that few IRFs are significant, since, for most of them, the 95% confidence interval, obtained by bootstrapping, includes the zero line. An exception are the IRFs obtained by a shock in the international price of cocoa, that has a lasting positive effect on itself and a negative one on the stock–to–grind ratio, this last fulfilling expectations. Similarly, the fertilizers and food price indexes generate IRFs with positive and significant impacts on themselves, despite the former only for initial years. Considering that cocoa is a perennial tree and not a yearly crop, it is reasonable to expect scarce short term effects on its produced quantity. Moreover, food and fertilizers price indexes are also likely to be exogenous in the short term with respect to cocoa related variables. However, also the price of cocoa beans seems to be insensitive in the short term to shocks in both indexes.

5.2 Short-term Dynamics: Price Transmission Analysis

Shifting the focus on the price transmission analysis, Table A1, in the Appendix, shows the coefficients of the error correction terms and of the differenced lags. Differently from the previous analysis, we comment directly IRFs rather than single coefficients, remembering that they can be interpreted as elasticities since the variables are in logarithms. Figure 5 shows the IRFs of all the four variables related to the price transmission analysis. Despite being all prices along the value chain of the same product, only some IRFs turn out to be significant. Furthermore, their magnitude is rather low, with absolute values occasionally reaching 0.06%. This is likely due to the monthly time scale, lowering the amplitude of the one standard deviation shocks compared to yearly data.

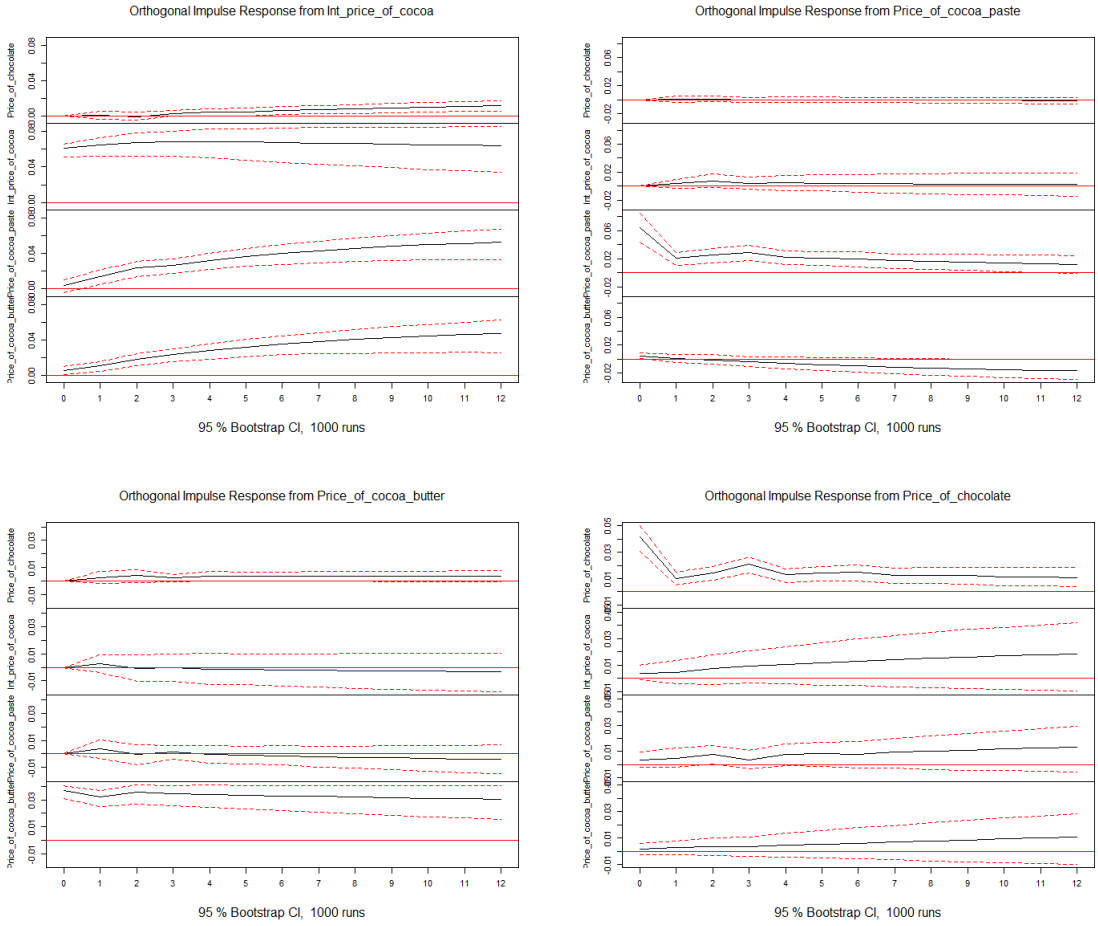
All variables positively and significantly impact themselves with a declining effect over time. Shocks in the international price of cocoa beans positively impact all prices but the magnitude and significance is far lower for chocolate products. This is reasonable since shocks to the price of cocoa beans are transmitted more directly to the products at the next

step of the value chain. It has to be further noted that the price of chocolate products is scarcely affected by shocks in all other prices, with shocks in the price of cocoa beans being actually the most impactful, followed by shocks in the price of cocoa butter, only marginally significant. The IRF describing the effect of the price of cocoa paste on the one of chocolate products is, instead, not significant. This is probably due to the broad definition of the chocolate products category, that includes items with only minor quantities of chocolate among their ingredients. Thus, sudden shocks in the cocoa value chain have very scarce short term consequences on the price of chocolate products.

The impact on the price of both cocoa paste and butter from shocks in the international price of cocoa beans is almost identical, with this result being reasonable since cocoa butter is directly derived from cocoa paste. The price of cocoa beans, instead, is never significantly impacted by shocks in other prices, explainable with the fact that cocoa beans occupy the first step of the value chain.

Finally, shocks in the prices of cocoa butter and paste do not seem to affect each other price, except for a mild negative effect from cocoa paste to butter at the end of the twelve months. This appears to be puzzling since, as mentioned, cocoa butter is derived from cocoa paste, thus a positive link was expected. Both the magnitude and significance of the negative response, however, evidence a very weak link in the short term between the two prices. The last aspect worth to mention is the inconsequentiality of shocks in the price of chocolate products on the other prices. As for the price of cocoa beans that is not impacted by shocks in other prices being at the beginning of the value chain, it is reasonable that shocks on the price of the product at the opposite side of the spectrum do not influence preceding goods. Demand driven shocks, however, could theoretically cause increases in the prices of products at a lower stage of the value chain. The present analysis seems to exclude this type of demand driven shocks along the cocoa VC. However, the broad definition of chocolate products could also cause a weakening in the effect of demand shocks.

Figure 5: IRFs for the Price Transmission Analysis Spanning 12 Months



5.3 Analysis of Structural Changes

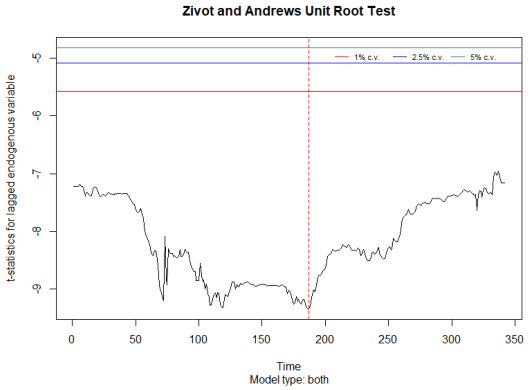
The last step in the analysis of the cocoa market fundamentals and of the price transmission inside its value chain regards structural changes. The Zivot and Andrews (2002) unit root test is applied to the predicted cointegrated equations and to the residuals in order to individuate their eventual presence. This test is able to endogenously generate structural changes and to test their statistical significance (Zivot and Andrews, 2002). Figure A4, in the Appendix, shows the predicted cointegrated equations for both types of analysis. Two predictions are shown in each plot since two cointegrating vectors are present in both

analyses. The Zivot and Andrews (ZA) test has been conducted with a drift and a time trend, since both were present in the VECM models, and by adopting the same number of lags.

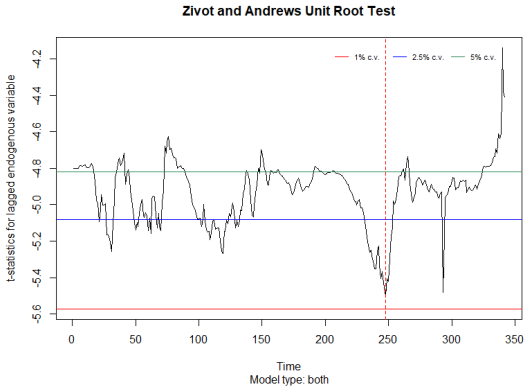
For the cocoa market analysis, the results of the ZA test are shown in Figure A5 in the Appendix. Over all plots, representing the two cointegrated equations and the residuals of the cocoa related variables, only the international price of cocoa beans has a statistically significant structural change in its residuals, at the 5% significance level. This happens at year 39, thus in 1999, a year that does not coincide with any major crisis or major event, such as the oil crisis of the late seventies or the global financial crisis of 2007–08. However, by looking at Figure reffig1, it is possible to see that the end of the previous century effectively sign the end of long trend of mild decline in the price of cocoa beans followed by a trend of similarly mild increase. All other plots, including the ones of the residuals of food and fertilizers price indexes (not shown), do not present any structural change. The link between fundamentals in the cocoa market does not seem to have incurred any major break, except for a change in the long term trend of the price of cocoa beans that could be explained by a rise in demand greater than the rise in production.

For the price transmission analysis, the results of the ZA test applied on the cointegrated equations and on the residuals of each variable are shown in Figure 6. All series have a significant structural change at the 1% level of confidence, except for the second predicted cointegrated equation, where the significance is at the 2.5% level. For the two cointegrated equations, the structural breaks occur at the end of 2010 and of 2015. By looking at Figure 2, it is possible to see that, in both cases, the break coincide with the end of a period of peak prices and the beginning of a rather sharp decrease in all prices except for the one of chocolate products. Furthermore, the end of 2010 coincides with a very mild upward long term trend in the price of cocoa beans, paste and butter, followed by a substantial stagnation in the price of the former two products (with fluctuations around a flat trend), while the price of butter continued an overall mild upward trend, with oscillations more pronounced than for the other prices. At the end of 2016, instead, it is the price of cocoa

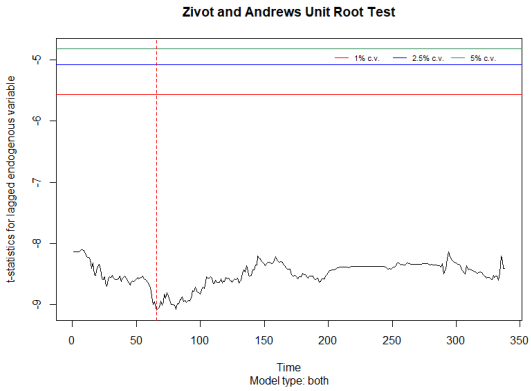
Figure 6: Structural Changes from the Zivot and Andrews Unit Root Test on the Predicted Cointegrated Equations and on the Residuals of the Price Transmission Analysis



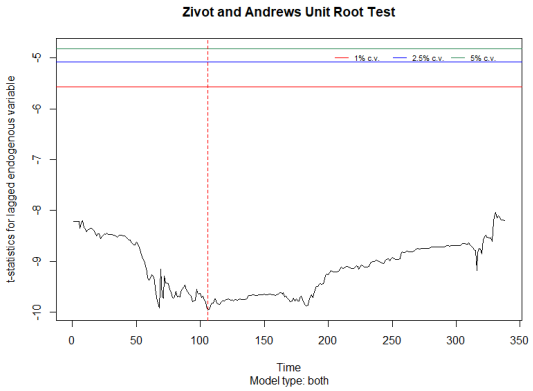
(a) Predicted Cointegrated Equation 1



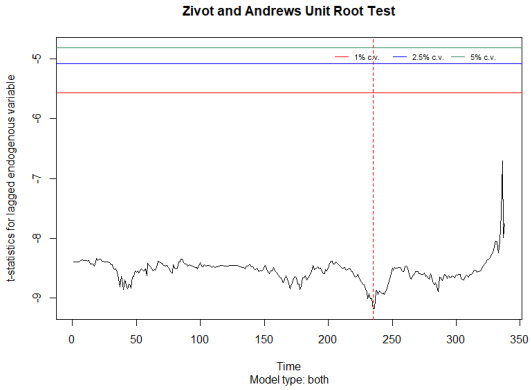
(b) Predicted Cointegrated Equation 2



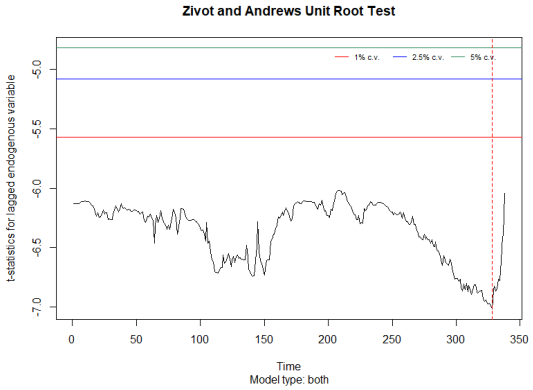
(c) Residuals: Int. Price of Cocoa Beans



(d) Residuals: Price of cocoa paste



(e) Residuals: Price of cocoa butter



(f) Residuals: Price of chocolate products

butter to decline more than the prices of cocoa beans and paste.

Shifting the attention on the residuals, it is possible to observe that the price of cocoa beans, paste, butter and chocolate products have structural breaks, respectively, in year 2000, 2004, 2015 and 2022. The break in the residuals of the equation describing the price of cocoa beans agrees with what observed in the yearly analysis, where a break is individuated in the year 1999. The break in the residuals series of the price of cocoa paste occurs in 2004, when the difference with the price of cocoa beans (Figure 2) starts to reduce while widening in comparison with the price of cocoa butter. Note that this trend starts to reverse five years later. The break in the residuals of the price of cocoa butter precedes of roughly one year the break in the second predicted cointegrated equation. The difference in the trend of the cocoa butter price series compared to the other prices has already been mentioned as a potential explanation. Finally, the break resulting from the residuals of the equation of chocolate products price coincides with the beginning of the sharp increase in prices of the last years. Chocolate products have actually not experienced such a dramatic price increase as the other products along the cocoa value chain. Despite a general unresponsiveness of the price of chocolate products to variations in other prices along the same VC, this has been exacerbated in the last years, signalling a potential break. However, the break could be temporary and the lower increase in the price of chocolate products could be due to stocks that may cause a delay in the response of this price series to the sharp movement of the others.

6 Conclusions

Cocoa, an internationally traded commodity consumed prevalently in industrialized countries and largely produced by smallholders in developing nations, Ivory Coast and Ghana in primis, has received considerable interest in the economic literature. Most studies, however, have a microeconomic and developmental perspective, focusing specifically on the livelihood of farmers and on their productivity. However, the way in which prices are formed internationally and transmitted along the cocoa value chain is also an important determinant of

the final income of smallholders since it determines the amount farmers will get for their produce.

Some studies have investigated both the mechanism of cocoa price formation, by looking at its fundamentals, and the transmission of prices along its value chain. Particular emphasis has been placed on evaluating the efficient market hypothesis and to assess the presence of oligopolistic/oligopsonistic behaviours inside the cocoa VC. While there is a certain agreement in rejecting the efficient market hypothesis, the presence of oligopolistic/oligopsonistic behaviours is a debated theme.

The present paper investigates both the fundamentals of the cocoa market and the price transmission along its value chain using VECM models. The former analysis, that uses yearly data from 1961 to 2022 and includes the price of cocoa beans, the global produced quantity, the stock-to-grind ratio and the price indexes of fertilizers and food products, reveals a long term positive relation between the international price of cocoa and both the fertilizers price index and the stock-to-grind ratio. The produced quantity, besides having a positive trend, is negatively influenced by this last variable, while it is not affected by neither of the two price indexes. In the short term, instead, shocks rarely produce statistically significant effects, with the confidence intervals of most IRFs crossing the zero line.

The price transmission analysis featuring monthly prices for cocoa beans, paste, butter and chocolate products inside the European Union from 1996 to mid 2024 reveals a positive effect of the prices of cocoa butter and paste on the price of chocolate. Furthermore, the price of cocoa paste drives up the international price of cocoa beans, signalling a potential demand effect. Both the prices of cocoa beans and chocolate products have a declining trend along time with the increased global production being a possible explanation for the former, while for the latter the explanation could either be improved efficiency or a shift on cheaper ingredients in the overall composition of this category. Both the prices of cocoa paste and butter, instead, display an increasing time trend, corroborating the hypothesis of Gilbert (2008) of increasing transformation costs.

With regard to short term effects, also in the price transmission analysis several IRFs are not significant. Only shocks in the international price of cocoa beans cause significant positive effects on the other prices, although with a very low magnitude in the case of chocolate products. No evidence of demand driven effects, with shocks on prices at higher steps of the value chain never significantly affecting prices at lower stages.

Finally, with regard to the examination of structural breaks, only the international price of cocoa, namely its residuals, shows evidence of a brake in the yearly analysis. This structural break is confirmed by the monthly analysis, where all residuals series and the predicted cointegrated equations have one significant break point.

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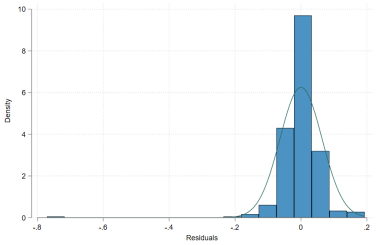
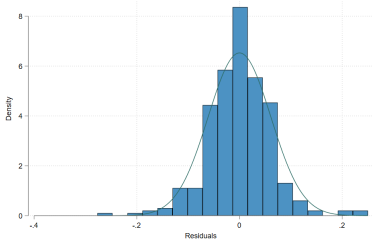
Appendix

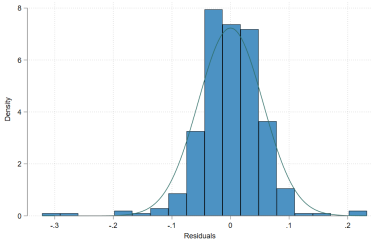
Figure A1: Distribution of Residuals from the Price Transmission Analysis with Variables in Levels



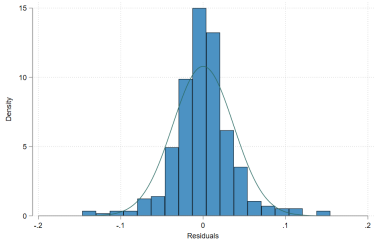
(a) Int. Price of Cocoa



(b) Price of Cocoa Paste



(c) Price of Cocoa Butter



(d) Price of Chocolate

Figure A2: World Cocoa Production with Allocated Land and Average Yields over Time

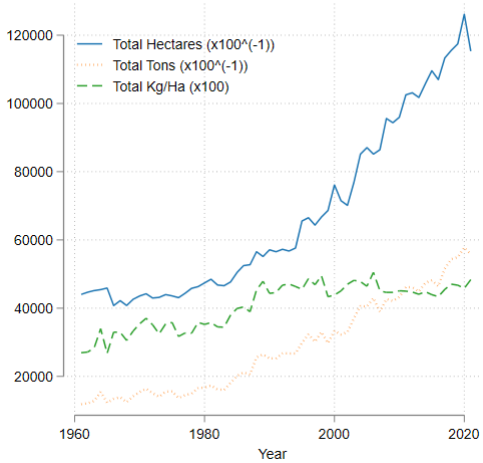


Figure A3: IRFs for the Cocoa Market Analysis Spanning 12 Years

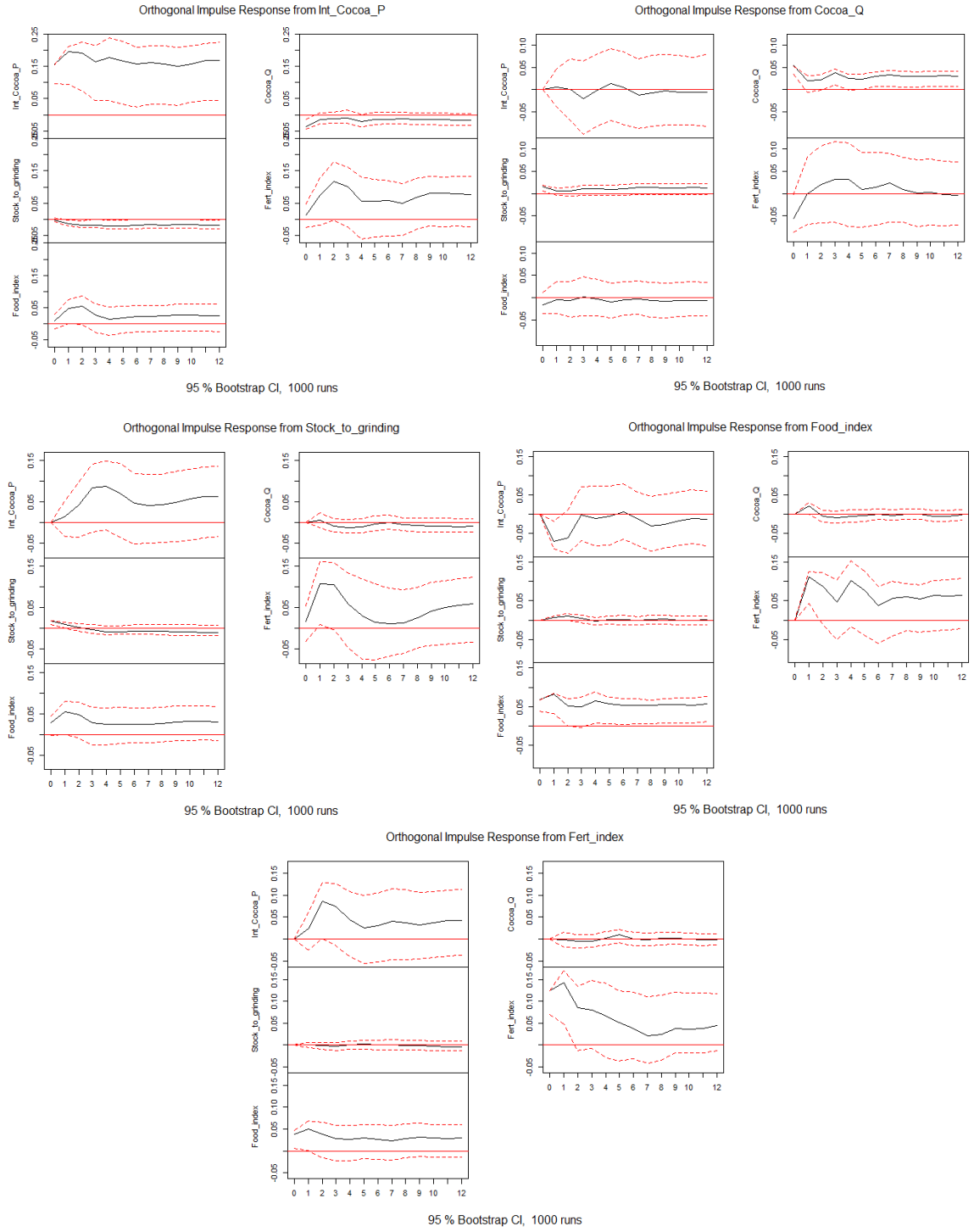
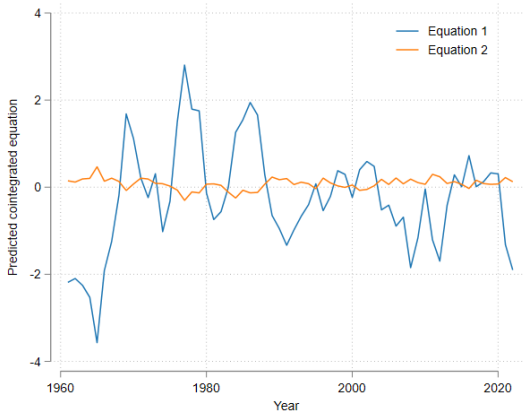


Table A1: Estimates for the VECM Regression for the Price Transmission Analysis

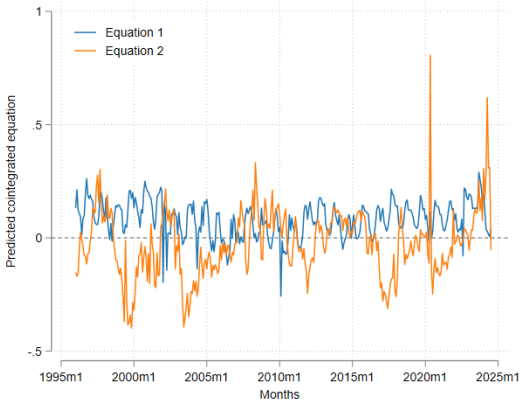
	Coefficient	P-value		Coefficient	P-value
Dependent: Int. price of cocoa			**Dependent: Price of cocoa butter**		
ECT_eq1	0.1612***	0.007	**ECT_eq1**	0.0791**	0.028
ECT_eq2	0.0307	0.393	**ECT_eq2**	0.0971***	0
Int. price of cocoa			***Int. price of cocoa***		
Δ*Lag 1*	0.0179	0.788	Δ*Lag 1*	-0.0076	0.851
Δ*Lag 2*	-0.0062	0.921	Δ*Lag 2*	0.0195	0.61
Δ*Lag 3*	-0.1194*	0.072	Δ*Lag 3*	0.1018**	0.011
Price of cocoa paste			***Price of cocoa paste***		
Δ*Lag 1*	0.1072*	0.065	Δ*Lag 1*	0.0456	0.194
Δ*Lag 2*	0.1309**	0.025	Δ*Lag 2*	0.0164	0.644
Δ*Lag 3*	-0.0036	0.942	Δ*Lag 3*	0.0114	0.705
Price of cocoa butter			***Price of cocoa butter***		
Δ*Lag 1*	0.0529	0.556	Δ*Lag 1*	-0.1383**	0.011
Δ*Lag 2*	-0.0579	0.527	Δ*Lag 2*	0.0758	0.171
Δ*Lag 3*	0.1253	0.174	Δ*Lag 3*	0.0985*	0.078
Price of chocolate			***Price of chocolate***		
Δ*Lag 1*	-0.1896**	0.016	Δ*Lag 1*	-0.0557	0.241
Δ*Lag 2*	-0.1661**	0.038	Δ*Lag 2*	-0.0324	0.503
Δ*Lag 3*	-0.1119	0.108	Δ*Lag 3*	-0.0311	0.461
Months	0.0005	0.698	*Months*	0.0019**	0.025
Const.	-0.0129	0.278	*Const.*	-0.0142	0.048
Dependent: Price of cocoa paste			**Dependent: Price of chocolate**		
ECT_eq1	0.0301	0.628	**ECT_eq1**	-0.3114***	0
ECT_eq2	0.2435***	0	**ECT_eq2**	-0.0063	0.847
Int. price of cocoa			***Int. price of cocoa***		
Δ*Lag 1*	-0.0317	0.648	Δ*Lag 1*	0.0079	0.896
Δ*Lag 2*	0.0249	0.707	Δ*Lag 2*	-0.0307	0.592
Δ*Lag 3*	-0.1076	0.121	Δ*Lag 3*	0.0087	0.885
Price of cocoa paste			***Price of cocoa paste***		
Δ*Lag 1*	-0.463***	0	Δ*Lag 1*	0.0125	0.811
Δ*Lag 2*	-0.2747***	0	Δ*Lag 2*	0.0371	0.483
Δ*Lag 3*	-0.2046***	0	Δ*Lag 3*	0.0129	0.773
Price of cocoa butter			***Price of cocoa butter***		
Δ*Lag 1*	0.1265	0.177	Δ*Lag 1*	-0.0288	0.722
Δ*Lag 2*	0.0255	0.79	Δ*Lag 2*	0.0934	0.259
Δ*Lag 3*	0.1599*	0.097	Δ*Lag 3*	0.0428	0.607
Price of chocolate			***Price of chocolate***		
Δ*Lag 1*	0.0659	0.421	Δ*Lag 1*	-0.167**	0.018
Δ*Lag 2*	0.1019	0.222	Δ*Lag 2*	-0.0349	0.629
Δ*Lag 3*	-0.02	0.784	Δ*Lag 3*	0.0395	0.53
Months	0.0003	0.84	*Months*	0.0053***	0
Const.	0.007	0.57	*Const.*	-0.0096	0.37

Significance levels: *=10%, **=5%, ***=1%

Figure A4: Predicted Cointegrated Equations for the Cocoa Market and Price Transmission Analysis

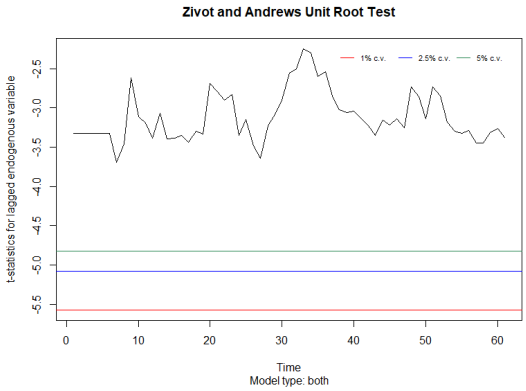


(a) Cocoa market



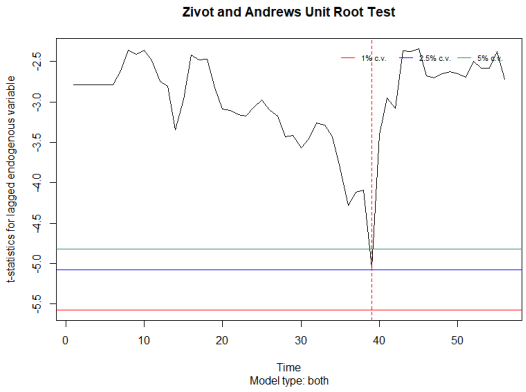
(b) Price transmission

Figure A5: Structural Changes from the Zivot and Andrews Unit Root Test on the Predicted Cointegrated Equations and on the Residuals of the Cocoa Market Analysis



(a) Predicted Cointegrated Equation 1

(b) Predicted Cointegrated Equation 2



(c) Residuals: Int. Price of Cocoa Beans

(d) Residuals: World cocoa quantity

(e) Residuals: Stock–to–grind ratio