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The role of the coffee futures market in discovering prices for Latin American producers

Background

1. In accordance with Article 34 of the International Coffee Agreement 2007 and the Programme of Activities for coffee year 2017/18, the International Coffee Organization (ICO) is required to provide Members with studies and reports on relevant aspects of the coffee sector.

2. The Five-Year Action Plan of the Organization sets out as one of the priority actions under Strategic Goal I 'Delivering world class data, analysis and information' the establishment of partnerships with universities and research institutes. The aim for these collaborations will be to improve the quantity and quality of analytical output produced by the ICO.

3. As a first step in building and formalizing partnerships with universities, during coffee year 2017/18, the Secretariat has started to collaborate with the Department of Agricultural Economics and Rural Development at Georg-August University of Goettingen, Germany. The objective of the collaboration is to combine ICO coffee market data and in-house research capabilities with advanced analytical tools employed by university researchers in producing comprehensive research studies. These studies are technical in nature and are aimed at an audience of sector specialists and researchers working in the area of applied economics of the coffee sector and will be disseminated within the research community. The Annexes include a detailed account of the methodology used to allow for replication by researchers, e.g. in national research institutes. The studies also include an extended summary in non-technical language.

4. Since the start of the collaboration, joint research has been carried out in the area of coffee prices, trade patterns and gender equality. The first study has been finalized and is attached to this document. This study on the role of futures markets for price discovery in Latin American markets analyses the relationship between the spot and futures market for coffee in Brazil, Colombia, Guatemala, Honduras, the Dominican Republic and El Salvador.

5. Two further studies, the assessment of the gender productivity gap in Ethiopian coffee production using World Bank census data, and an analysis of Certificates of Origin data for exports from selected producing countries in Asia and Latin America are currently ongoing with completion expected in coffee year 2018/19.

Action

6. The Council is requested to take note of this document.

SUMMARY

Coffee is an important export commodity for many Latin American countries with a share in total export value in 2016 ranging from around 2% in Brazil and El Salvador to more than 11% in Honduras. Coffee is also actively traded at international commodity exchanges. Therefore, it is important to understand the relationship between the prices set for coffee futures, a contractual obligation to sell the commodity at a predetermined day in the future, and spot prices, that is the current market price for immediate delivery of the coffee. Previous research is divided on the direction of the relationship between spot prices and futures prices. While some studies find that coffee futures markets dominate the price discovery process, others suggest that spot markets incorporate new information faster.

The objective of this study is to contribute to the debate by (i) investigating the relationship between spot market and futures prices for coffee, and (ii) analysing the role of futures markets as a price discovery mechanism using ICO price data from six coffee-producing countries in Latin America: Brazil, Colombia, Guatemala, Honduras, El Salvador and the Dominican Republic.

This study is based on monthly observations c sc4 1a-410h.

ABBREVIATIONS

ADF	Augmented Dickey-Fuller Test
AIC	Akaike Information Criterion
ANACAFE	Asociación Nacional del Café
FEDECAFE	Federación Nacional de Cafeteros de Colombia
ICA	International Coffee Agreement
ICE	Intercontinental Exchange
ICO	International Coffee Organization
IHCAFE	Instituto Hondureño del Café,
IS	Information Share
Liffe	London International Financial Futures and Options Exchange
NYBOT	New York Board of Trade
PT	Permanent-transitory model
VECM	Vector Error Correction Model

THE ROLE OF THE COFFEE FUTURES MARKET IN DISCOVERING PRICES FOR LATIN AMERICAN PRODUCERS[1]

I. INTRODUCTION

1. Coffee is an important commodity for a number of tropical lower and middle-income countries and a relevant source of export revenues and tax collection. It contributes significantly to the GDP of many producing countries (da Silveira, Mattos, and Saes, 2017). Coffee prices are characterized by substantial short-term fluctuations (Mohan and Love, 2004). High price volatility combined with a low price level puts less developed countries relying on coffee at risk (Fortenbery and Zapata, 2004). Price spikes and crashes, caused, for example, by environmental factors such as droughts and frost, can be a major source of macroeconomic instability (Fry, Lai, and Rhodes, 2010).

2. Coffee is produced by about 25 million farmers worldwide; the vast majority being smallholder producers (da Silveira 2017). They are particularly vulnerable to volatile prices due to a limited ability to hedge their risks or diversify their production (Mohan and Love, 2004). While the coffee sector has a long-standing history of regulation, over the past decades the market became gradually more liberalized. Many developing countries started to implement structural adjustment reforms in the 1980s and 1990s, including liberalization of export crops and the abolition of marketing boards (Subervie, 2009). Previous studies point to an increased transmission of price fluctuations to domestic market prices as a result of the implemented reforms (Krivonos, 2004; Mofya-Mukuka and Abdulai, 2013; Subervie, 2009). The reforms also increased the share of producer prices in the world market price, yet as the coffee value chain also became increasingly concentrated, a substantial amount of power and income was transferred to roasters and retailers in high income countries. Due to this development, small producers and exporting countries are vulnerable and tend to be most affected by price swings (da Silveira , 2017).

3. Coffee is also actively traded at international commodity exchanges. Futures markets in general can be used as a risk management instrument, since market participants are able to hedge commodities against the risk of adverse price fluctuations (Fry , 2010). Furthermore, transparent price discovery and price dissemination are considered as the main potential uses of futures markets. Future price quotes for commodities traded in well-established international exchanges may thus serve as a useful proxy for price expectations. Advances in communication and information technologies also made information accessible even for producers in remote areas (Mohan and Love, 2004).

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4. Yet previous research is divided on the direction of the relationship between spot and futures prices. There is evidence that coffee futures markets are dominating the price discovery process (Fortenbery and Zapata, 2004; Mattos, Garcia, and Louis, 2004), but there are also indications of a bi-directional relationship between spot and futures markets (Fry ., 2010; Mohan and Love, 2004).

5. The objective of this study is therefore to contribute to the debate in terms of investigating this relationship of spot market and futures prices and to analyse the role of futures markets as price discovery mechanism. If futures prices are to serve as a proxy for price expectations, it is important to better understand the relationship between spot and futures prices and to determine where prices are discovered.

6. This study investigates the following research questions:

i. Does a stable relationship exist between coffee futures and producer prices?
ii. Is the coffee futures market the primary source of price discovery, processing new market information more swiftly than the local market?

7. The remainder of the study is structured as follows: in Section 2, the role of the futures market in price discovery is discussed. Sections 3 and 4 provides an overview of the functioning of the coffee futures market as well as evidence on the relation between spot and futures markets. Section 5 describes the data used and the methodological approach. Results of the analysis will be presented in Section 6, followed by a conclusion and outlook in Section 7.

II. COMMODITY FUTURES MARKETS AND PRICE DISCOVERY

8. The role of futures market is to provide an instrument for market participants to hedge their price risk. Futures prices reflect the combined views of a large number of buyers and sellers expressing their expectations of the future value of a certain commodity. The traders' expectations are based on the information available at the time the price is recorded. As the expiry of a futures contract approaches, new market information becomes available. This causes the trader's perception of supply and demand to alter, resulting in a change in market price (Fortenbery and Zapata, 1997).

9. Generally, cash and futures prices are expected to react to new market information in the same way. That is, if information on a decrease in the supply of coffee is received by the market, the futures price for a later delivery period of coffee increases. Given this new information, one would also expect the observed cash price for that specific period to be higher ( ).

10. If a commodity is traded in different markets, its price in any of these markets is discovered by news gathered and interpreted in these markets. As only the trading venue differs, arbitrage between these markets ensures that the prices in the different markets do not drift apart too far. They thus share a common stochastic factor. This factor can be referred to as the implicit efficient price driven by new information, making it the origin of permanent price movements in all markets (Baillie ., 2002).

11. A key feature of a futures market is price discovery, the process of incorporating new information into the market price and unraveling the fundamental market value (or "efficient price") of the underlying asset. Lehmann (2002) defines price discovery as "the efficient and timely incorporation of the information [...] into market prices" (p.259). Hasbrouck (1995) understands price discovery as "'who moves first' in the process of price adjustment" (p.1184) to innovations in the efficient price.

12. The question arises, whether the spot market or the futures market incorporates new market information faster and thus leads the process of discovering prices. Typically, a price series' contribution to price discovery is considered to be the extent to which it is the first to reflect new information about the underlying asset value. Overall, the value of a futures market lies in how well the price was discovered in such a market. Futures markets are thought to be a place to develop efficient predictors of subsequent spot prices. A futures market is considered efficient if the prices discovered there accurately reflect market participants' expectations of future demand and supply. This suggests that individual market participants would not be able to use available information to make more specific projections of future supply and demand information. It also holds implications for the relationship between futures and cash prices. If a futures market provides an efficient price discovery mechanism, market participants can use the information provided by the futures market to forecast future spot prices and as a basis for their decision making (Fortenbery and Zapata, 1997).

III. COFFEE FUTURES MARKETS

13. Coffee futures exchanges were created to organize the process of pricing and trading coffee while lowering the risk associated with the cash market. Coffee futures are standardized contracts to deliver or accept a given quantity and quality of coffee at one of a certain range of delivery ports. When engaging in futures trading, the parameters to be agreed upon are the number of contracts, the price and the period of delivery. The delivery period is chosen from a set of calendar months, called the trading position. The nearest delivery month is thus called 'First Position', the following 'Second Position' and so forth (International Trade Centre, 2011).

14. The futures exchange is an organized marketplace which supports five basic pricing functions: Price discovery, price risk transfer, price dissemination, price quality and arbitration. It provides facilities for trading, establishes and enforces rules of trading and disseminates trading data. As the exchange establishes a visible and free market setting for the trading of futures, it helps the underlying industry to find (discover) a market price for the product (.).

15. There are two main futures market centers for coffee: The Intercontinental Exchange (ICE) in New York, primarily trading Arabica, and the London International Financial Futures and Options Exchange (NYSE Liffe), which trades Robusta coffee. Coffee futures have a long trading history in New York, where they were traded as early as 1882. In 1998, the New York Board of Trade (NYBOT) was established as a parent company of the Coffee, Sugar and Cocoa Exchange (CSCE) and the New York Cotton Exchange (NYCE). The ICE and the NYBOT merged in January 2007, leading to the introduction of electronic trading for six NYBOT commodities, including coffee (Intercontinental Exchange, 2012).

16. The Coffee 'C' contract or NYSE traded at the ICE is the world benchmark for Arabica coffee. It prices physical delivery of exchange-grade green beans from one of 20 countries[2] of origin, mainly Latin American, to a licensed warehouse in one of several ports in the USA and Europe. It has five delivery months (March, May, July, September, and December) and has a volume of 37,500lbs. From the countries traded under investigation El Salvador, Guatemala and Honduras are traded at par. Colombia is traded at 400-point premium, while the Dominican Republic and Brazil are traded at 400- and 600-point discounts. Brazilian coffee has only been deliverable from the expiration of the March 2013 contract onwards. Bids and offers are quoted in US cents/lb. All coffee submitted for tendering needs to obtain a certification of grade and quality from the exchange first. There are six evaluations and measurements, based on which the quality is determined. These include coffee odour, screen size, colour, defect count, roast uniformity and cup ( ).

17. The major difference between a (coffee) futures market and the spot market is that in a futures context one deals with standardized qualities and lot sizes. Futures contracts do not involve an immediate transfer of ownership of the commodity involved. In the spot market, participants trade physical, green coffee of different qualities. The coffee will be delivered immediately or at a later date, and the transaction in the cash market is based on an actual transfer of ownership. The cash price is the current local price for a very

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specific product. The futures price, on the other hand, is the price market participants expect to pay or receive for coffee at some point in the future, depending on the traded position. Though the futures transaction is centered around physical coffee, very few contracts lead to an actual delivery of the commodity. Traders in the futures market are rather focusing on risk management or investment opportunities than on the physical exchange of coffee (International Trade Centre, 2011).

18. The futures price represents an average price of available coffee, as the contract is based on a standardized quantity and quality of the commodity. The difference between cash and futures prices, positive or negative, is called basis or differential. As the expiration date of the contract draws closer, cash and futures prices tend to converge (.).

19. Trading volume is a crucial factor for the success of a futures exchange. Large transaction volumes provide flexibility for traders, giving them the opportunity to pick the most appropriate contract months to hedge their price risk. The higher the number of traders (buyers and sellers) in a futures market, the more efficient is this market in pricing the underlying asset. Volume not only affects futures prices but inevitably has an impact on the price of coffee in the physical market. Therefore, the coffee industry regularly examines and publishes positions of speculators and hedgers in the market (International Trade Centre, 2011).

IV. EXISTING EVIDENCE ON THE RELATIONSHIP OF SPOT AND FUTURES PRICES IN COFFEE

20. Looking at the relationship of coffee spot and futures markets, Kebede (1993) tested the coffee futures market in New York for causality and rationality. The author finds indications that futures prices strongly influence variations in spot prices eight weeks or more to maturity, though from seven weeks to maturity the relationship between the two markets seems to be bi-directional. In general, the author finds that futures prices can be used as indicators of spot prices 55-77 weeks prior to maturity.

21. Sabuhoro and Larue (1997) tested the market efficiency hypothesis for coffee and cocoa futures. They find cash and futures markets to be cointegrated, though short-run deviations from equilibrium occur. Nevertheless, the study found the futures market for coffee to be overall efficient and unbiased. Market efficiency was also studied by Kristoufek & Vosvrda (2014), who analysed futures markets for coffee among a total of 25 commodities. The authors used an efficiency index and found the coffee futures market to be among the most efficient markets.

22. Using a cointegration framework, Fortenbery and Zapata (2004) found a stable relationship between the New York futures market and two Central American countries. While the futures market seemed to have a large effect on the cash market, the influence of the latter on futures prices seemed to be comparatively low. They concluded that using New York contracts can function as a hedging vehicle and would result in a reduction of price risk for market participants in these countries. On the other hand, Mohan and Love (2004) conduct a regression analysis and find a bi-directional relationship between spot and futures prices. The authors concluded that futures prices were not efficient in predicting subsequent spot prices. Fry . (2010) also found a bi-directional relationship between spot and futures markets. Yet they found the effects of the two markets not to be constant over time. In earlier periods, the futures market seemed to have a stronger influence, while over time, the spot market influence on the futures market increased.

23. The effects of futures trading activity on price discovery is examined by Mattos (2004). The authors studied several agricultural futures markets, including coffee, in Brazil. While for most of the commodities under investigation the authors failed to found a stable long-run relationship, the coffee spot and futures markets seem to be cointegrated. They concluded that trading volume plays a role in the relationship between the two markets and that futures play a dominant role in the more actively traded coffee sector.

24.

V. DATA AND ECONOMETRIC APPROACH

25. This study is based on ICO data comprising monthly observations of Arabica coffee prices from January 1973 to March 2017. The producer price series used in the analysis contains monthly observations of Arabica coffee prices for Brazil, Colombia, Guatemala, Honduras, El Salvador and the Dominican Republic. Brazil, Colombia, and Honduras were primarily selected based on their great importance in coffee production. The length and

the completeness of the price series were another selection criterion, based upon which Guatemala, El Salvador, and the Dominican Republic were chosen from the range of producing countries in Latin America. The price series reflect prices paid to producers and are collected by institutions in the producing countries and reported to the ICO. All prices are reported in US cents/lb and given in nominal exchange rates.

26. For the futures prices, the monthly average from the second and third trading position futures contracts from the ICE is computed. As NYBOT and ICE merged in 2007, the futures price data cover coffee traded at NYBOT up to 2007. Following the merge, prices are based on contracts traded at the ICE. The futures prices are also given in US cents per lb and obtained from the ICO database.

27. Figure 1 and 2 illustrate the price development of local producer prices and the New York futures prices for the whole period. Two patterns emerge from the illustration. Firstly, all price series appear to follow a similar movement with peaks in the mid-1970s, mid-1980s and two peaks in the 1990s. Following the coffee price crisis in the late 1990s and the historically low price level in the early 2000s, producer and futures prices seem to follow a steady upward trend up to 2011. After a decreasing temporarily, prices started to recover in late 2013/ early 2014.

28. Secondly, for most of the period, futures prices are in contango[3], i.e. higher than local producer prices. Only on rare occasions, single producer price series exceed the futures price and the futures market is in slight backwardation.

29. The empirical analysis comprises three steps:

(a) Identifying structural breaks

An appropriate timeframe for the analysis will be identified by using the residual-based test for cointegration introduced by Gregory and Hansen (1996) (see technical Annex I). Different events had an impact on the coffee sector as such (e.g. the collapse of the quota system in 1989). A change in the relationship between the New York futures market and a single country may yet be connected to a specific event in a single country, which had no effect on other producing countries (such as national policy reforms). A breakpoint will thus be investigated for each country/New York futures market pair separately (see technical Annex I).

(b) Testing for cointegration of futures and producer prices

The price series will be tested for a unit root using the Augmented Dickey-Fuller (ADF) test. If the prices are found to be integrated of the same order, each country and the futures market pair will be tested for cointegration by employing the method introduced by Johansen (1988, 1991). Having ensured the existence of a cointegrating relationship between the price pairs, a Vector Error Correction Model will be estimated using Johansen's ML approach (see technical Annex II).

(c) Determining each market's contribution to price discovery

To determine the contribution of the domestic and the futures markets to price discovery, the approach introduced by Hasbrouck (1995) and Gonzalo and Granger (1995) will be used (see technical Annex III).

VI. ESTIMATION RESULTS

30. As there is no clear theoretical indication on which model to use, all model specifications are estimated. Results are presented in Table 1. In Brazil, most test statistics indicate a break in March, April or May 1992. The break date is chosen in April 1992, being indicated by both the model assuming a shift in the intercept with and without a time trend. Furthermore, this break date is statistically significant on a 1% level and has the smallest values for the Phillips $V_{ç}$ test statistic.

Table 1: Gregory Hansen Test Results on Structural Breaks in the price time series

		Level Shift		Regime Shift		Level Shift with Trend		Regime Shift with trend	
Country	Test type	Break Point[a]	Test Statistic[b]	Break Point[a]	Test Statistic[b]	Break Point[a]	Test Statistic[b]	Break Point[a]	Test Statistic[b]
Brazil	ADF	1990/06	-5.07**	1992/12	-5.51***	1992/05	-5.11**	1991/09	-5.69**
	Phillips	1992/04	-5.35 ***	1994/06	-5.80***	1992/04	-5.41**	1992/03	-5.94**
Colombia	ADF	1989/03	-5.72***	1989/03	-5.72***	1989/03	-5.93***	2002/09	-6.17***
	Phillips	1989/01	-6.13***	1989/02	-6.44***	1989/02	-6.28***	1989/02	-6.55***
Guatemala	ADF	1997/12	-7.45***	1997/12	-7.51**	1988/03	-8.75***	1986/09	-9.22***
	Phillips	1997/12	-8.28***	1997/08	-8.37***	1987/10	-10.16***	1986/08	-10.67***
Honduras	ADF	2001/09	-9.43***	1994/09	-9.49***	1979/09	-10.33***	1986/02	-10.72***
	Phillips	2001/08	-9.11***	1994/10	-9.15***	1979/09	-10.23***	1986/02	-10.65***
Dominican Republic	ADF	2009/11	-5.16***	2010/05	-5.46**	1984/10	-6.26***	1984/08	-6.44***
	Phillips	1990/07	-5.17***	2010/05	-5.46**	1984/10	-6.35***	1985/02	-6.79***
El Salvador	ADF	1979/08	-5.29***	1986/03	-5.82***	1979/08	-5.78***	1988/11	-7.37***
	Phillips	1979/08	-5.43***	1994/07	-5.83***	1979/08	-6.02***	1988/11	-7.28***

[a] In all cases, both Phillips statistics indicated the same break date; only Z_t statistics presented here

[b] Z_t test statistics; -*,-**,-*** indicating statistical significance on a 10%, 5% or 1% level, respectively

31. For Colombia, all model specifications and test statistics unequivocally suggest a structural break in early 1989. Only the ADF test statistic for the specification assuming a break in level, slope and time trend indicates a structural break in late 2002. Yet as a break in 1989, the year when quotas were abolished, is strongly supported by all model specification, the date of the structural break in Colombia was chosen as March 1989.

32. A break in late 1997 in Guatemala is indicated by both the model specifying a shift in the intercept and the specification assuming a change in intercept and slope. While the other specifications indicate a break roughly ten years earlier, the date for the structural break is set for December 1997. Guatemala suffered from a civil conflict from 1960 to 1996, so a change in the relationship between Guatemalan producer prices and New York futures prices is assumed to have occurred after the end of the conflict.

33. For Honduras, each model specification indicates a different break date. A break in August 2001 is chosen, taking the coffee price crisis the period of substantially low prices as event introducing change in the relationship of New York futures prices and producer prices in Honduras.

34. Depending on model specification, different break dates are also indicated for the Dominican Republic. Given its proximity to the collapse of the quotas in July 1989, the date for the structural break is set for July 1990, assuming a shift in the intercept.

35. For El Salvador, the break is assumed to be in July 1994. For El Salvador, too, the different model specifications indicate differing break dates. Yet like Guatemala, El Salvador suffered from a civil conflict, lasting from 1979 until 1992, which had a strong impact on the coffee sector. Therefore, a change in the relationship between New York futures and local producer prices at the end of the conflict seems likely.

36. After identifying the appropriate time frame for each country, the price series are tested for unit roots in the period following their respective structural break. The results of the stationarity tests conducted for the price variables of the different countries are presented in Table 2. To ensure that the futures price series is also integrated of the same order as the producer price series in each particular time frame, it is tested for a unit root in all periods. As the ADF test cannot reject a unit root in price levels but in first difference, the price series are all assumed to be I(1).

Table 2: ADF test results, including constant but no time trend

	Time frame	No of observ.	Test statistic[a]		p-value	
			Level	First Difference	Level	First Difference
Brazil	1992/05-2017/03	299	-1.979	-13.564	0.2961	0.000
Futures market[b]			-1.941	-14.181	0.3132	0.000
Colombia	1989/04-2017/03	336	-1.549	-15.814	0.5090	0.000
Futures market			-1.835	-14.923	0.3630	0.000
Guatemala	1998/01-2017/03	231	-1.807	-19.447	0.3771	0.000
Futures market			-1.391	-12.770	0.5866	0.000
Honduras	2001/09-2017/03	187	-2.552	-17.042	0.1033	0.000
Futures market			-1.889	-11.647	0.3371	0.000
Dom Rep	1990/08-2017/03	320	-1.636	-16.994	0.4641	0.000
Futures market			-1.797	-14.784	0.3817	0.000
El Salvador	1994/08-2017/03	272	-1.835	-16.409	0.3631	0.000
Futures market			-1.907	-15.720	0.3288	0.000

[a] Critical values: -3.45, -2.88 and -2.57 for 1%,5% and 10% level of significance, respectively

[b] Futures market appearing several time as in each period, the futures price series was tested for a unit root

37. Given that all price series are integrated of the same order and present non-stationary I(1) series, the Johansen approach is used to test if producer prices and the futures prices are cointegrated. Results are given in Table 3. Based on the trace test statistic, the null hypothesis of no cointegration can be rejected in all cases at least on a 5% level. The null hypothesis of the existence of a cointegrating relationship cannot be rejected. Based on the cointegration test results, the first hypothesis of a stable long-run relationship between the futures and producer prices can be accepted. They thus share a common stochastic factor and react to the same set of information.

prices seem to have no impact in the short-run. Current producer prices in Colombia and Guatemala appear to be affected by past futures prices, and first and second order autocorrelation in futures prices can be found in both of these models. In the case of El Salvador, only the futures prices' second lag appears to have a statistically significant impact on current producer and futures prices. Past producer prices from Brazil appear to have no impact on current futures prices. On the other hand, results show that the past month's producer prices from Colombia seem to have an impact on current futures prices. Similarly, past futures prices appear to influence Colombian producer prices, but seemingly have no impact on producer prices in Brazil. While past producer prices from Guatemala appear to affect current futures prices, producer prices from Honduras do not. Futures prices from the previous month also seem to have an impact only on current producer prices in Guatemala, yet not in Honduras.

40. Though the AIC indicated the use of four lags in the VECM describing the relationship between Brazilian producer prices and New York futures prices, none of the lags seem to be statistically significant. This appears to be the case for both lagged producer and futures prices. Similarly, none of the two lags in producer and futures prices show to be statistically significant in Honduras. Past producer prices have no impact on current futures prices in four out of six cases. Nevertheless, in three cases there appears statistically significant autocorrelation in producer prices.

41. /v (]À }µš }(•]Æ • •U šZ iµ•šu vš ‰Œ u š Œ• r • El Salvador, both adjustment parameters are positive and statistically significant, in all other cases, the coefficient for the producer prices is negative. In five out of six cases, only the futures price series' adjustment coefficient is statistically significant and, in all cases, positive. In Honduras, only the adjustment coefficient of the producer price series is statistically significant. Only in Guatemala, is the adjustment coefficient for both price series statistically significant.

Table 4: Vector Error Correction Results

Country	Equation	»	‰ š? Ú	‰ š? Û	‰ š? Ü	‰ š? Ý	Œ š? Ú	Œ š? Û	Œ š? Ü	Œ š? Ý
Brazil	¿LÖ ç	-0.0511 (0.0642)	0.0222* (0.1126)	0.0084 (0.1135)	0.1341 (0.1106)	0.0547 (0.1098)	0.0223 (0.1335)	0.0003 (0.1337)		

Standard errors in parenthesis; -***,-**,-* indicating statistical significance on a 1%, 5% and 10% level, respectively.

42. In Honduras and Guatemala on the other hand, the producer prices' adjustment coefficients are much larger and statistically significant on a 1% level. Both countries have a larger adjustment coefficient than the futures market. The difference is particularly large in Honduras, and in this case the futures market's alpha is also insignificant. In Guatemala, both long-run adjustment parameters are statistically significant, yet the producer prices appear to show substantially stronger reaction to disequilibria than the futures prices. Though the Dominican Republic shows only a very small and statistically insignificant alpha, futures prices from the previous month appear to have an impact on current producer prices in the country. While the future price series shows a positive and statistically significant adjustment parameter, the coefficient remains very small.

43. For El Salvador both adjustment coefficients are positive and statistically significant. Yet the futures market appears to react more strongly to deviations from equilibrium. It also appears that previous futures prices have an impact on current producer prices in El Salvador. Interestingly, it is the second lag of futures prices which seems to affect prices in El Salvador. Yet, it is also the producer prices second lag which appears to influence current futures prices.

44. Based on the VECM results, the price discovery metrics are calculated. Table 5 ‰Œ • vš• šZ Œ •µoš• }(šZ ‰Œ]]• }À ŒÇ v oÇ•]•X , presented in column 3 from the VECM estimation, they can be used for the computation of the vector of common factor weights. Column 4 presents the Ûcoefficients from the PT model, column 5 and 6 the upper and lower bound IS, respectively, and column 7 the mid-point of the two previous columns.

45. Generally, the results from the price discovery analysis indicate an apparent bi-directional flow of information between the producer and the futures market. However, the larger share of information is taken up in local producer prices. Considering the average between upper and lower bound IS, in four out of six cases the IS and PT metric produce similar results. In the case of the Dominican Republic, the results of the two models are comparatively far apart, yet hold the same implications. For El Salvador, the estimation of the PT model was inconclusive and the computation of the IS not -

Table 5: Price Discovery Results

Country	Equation	r	PT	IS		
				Upper bound	Lower bound	ISø
Brazil	$L^{Ù}_{ç}$	-0.0511	0.3007	0.5812	0.0471	0.3142
	$L^{ã}_{ç}$	0.1189	0.6993	0.9528	0.4188	0.6858
Colombia	$L^{Ù}_{ç}$	-0.0317	0.2606	0.4989	0.1012	0.3001
	$L^{ã}_{ç}$	0.09	0.7394	0.8988	0.5011	0.6999
Guatemala	$L^{Ù}_{ç}$	-0.229	0.6856	0.7427	0.5525	0.6476
	$L^{ã}_{ç}$	0.105	0.3144	0.4475	0.2573	0.3524
Honduras	$L^{Ù}_{ç}$	-0.5535	0.9385	0.9827	0.8982	0.9405
	$L^{ã}_{ç}$	0.0363	0.0615	0.1018	0.0173	0.0595
Dominican Republic	$L^{Ù}_{ç}$	-0.001	0.0254	0.3461	0.0009	0.1735
	$L^{ã}_{ç}$	0.0552	0.9746	0.9991	0.6539	0.8265

46. Turning to the bounds of the IS, in four out of five cases, both upper and the lower bound hold the same implication regarding which market leads the price discovery process. Solely in the case of Brazil, implications change depending on which market is first in the estimation. In all other cases, upper and lower bound IS also confirming the findings from the PT model.

47. The width between the upper and lower bound of the IS is generally speaking a result of the correlation between futures and producer prices. Table 6 presents the correlation coefficients between local producer prices and the futures market error terms. Correlation appears to be highest between Brazilian producer prices and the New York futures prices, and smallest between Honduras and New York. It can be seen that the higher the correlation between the two price series, the larger is the disparity between the bounds.

Table 6: Correlation Coefficients of VECM error terms

Country	Correlation Coefficient
Brazil	0.6036
Colombia	0.4445
Guatemala	0.1996
Honduras	0.1917
Dominican Republic	0.5637

48. For Brazil, both the PT and the IS model give similar results: roughly 70% of new information is incorporated first in the producer prices, and 30% by the futures market. Due to the comparatively high correlation between the Brazilian producer prices and the New York futures market, a high deviation between upper and lower bound IS can be observed. Depending on which market is considered first in the Cholesky factorization, implication even changes: If the futures market is considered first, its contribution to price discovery is close to 60%, yet if Brazilian producer prices are first, prices are discovered almost entirely on the local market. This might be related to the fact that Brazilian Arabica coffee only started to trade at the ICE in 2013 and is traded at a 600-point discount. Furthermore, Brazil has a well-established local futures market, the Brazilian Mercantile and Futures Exchange, where coffee is actively traded.

49. Following the PT model, almost 75% of price discovery occurs in the local market in Colombia, and only about one fourth on the futures market. When considering the IS, Colombia's share in price discovery is only slightly smaller. If the futures market is the first item

function of a futures market is closely linked to the trading activity at a market. Though Adämmer (2016) find that the futures market may lead the price discovery process even in thinly traded markets, they also show that the price discovery function of a market is indeed connected to trading volume. Overall, as most of Dominican coffee is consumed domestically, it is not surprising that local supply and demand factors play a primary role in explaining the market value of coffee in the Dominican Republic.

52. Finally, in El Salvador the results of the PT model are not interpretable and show the limitations of this approach. To be interpretable, the factor weights need to be bounded by [0, 1]. This is only the case if the adjustment coefficients of the two markets have differing signs, a condition violated in this case. Therefore, a computation of the IS is also not possible. El Salvador's small part in global coffee production might play a role here. Furthermore, the country suffered from a civil conflict which heavily affected the coffee sector. The lack of stable institutions and the role of the middlemen might also have an impact on the relationship between futures and producer prices.

53. The price discovery metrics indicate that, in most cases, local producer prices incorporate new information faster than the futures market. Though futures and producer prices appear to react to the same set of information, indicated by the existence of a stable long-run equilibrium between futures and producer prices, Latin American producers may not generally use information provided by the futures market as a basis for their decision making. Nevertheless, for Guatemala and Honduras the New York futures market overall appears to take up information faster. This indicates that here, the futures market provides an efficient price discovery mechanism.

VII. CONCLUSION

54. Coffee is an important export commodity for many Latin American countries and is actively traded at international commodity exchanges. Therefore, understanding the relationship between well-established futures markets and producer prices for coffee is important. **The aim of this study was to analyse the relationship between the spot and futures market for coffee in different Latin American countries and to investigate whether the spot or the futures market leads the price discovery process.**

55. The analysis used monthly producer price data for Arabica coffee from six different Latin American countries: Brazil, Colombia, Guatemala, Honduras, the Dominican Republic and El Salvador. The futures prices are denoted as monthly averages from second and third position coffee \`C´ futures contracts from the ICE in New York.

56. The analysis was based on the two hypotheses that, firstly, as the two markets react to the same set of information, there exists a stable relationship between coffee futures and producer prices, and secondly, futures markets provide a price discovery vehicle.

57. Overall, the results support the assumption of a stable long-run relationship between futures and producer prices. **Cointegration could be found between all futures/producer price pairs, indicating that the price series share a common stochastic factor and react to the same set of information.** Furthermore, the results show that in most cases, the futures market reacts more strongly to disequilibria. Past futures prices seem to influence both current futures and current producer prices in most of the cases. Past producer prices seem to have an only limited influence on current futures levels.

58. Regarding the second hypothesis, findings are ambiguous. **In Brazil, Colombia, and the Dominican Republic, local producer prices appear to incorporate new information faster than the futures market.** This can be attributed to factors such as the size of the market (Brazil, Colombia), the existence of a sufficiently liquid exchange in the country (Brazil), and strong domestic consumption (Brazil, Dominican Republic).

59. **In Guatemala and Honduras, the New York futures market indeed dominates price discovery.** This suggests that producers in these two countries may benefit from taking their decisions based on futures price information. Information could be made more accessible for the producer, e.g. via extension work, local cooperatives or traders. For El Salvador, an estimation was not possible due to methodological limitations.

60. The study helped to better understand the role of well-established coffee futures markets for Latin American producers. Though it gave insight into the suitability of futures markets as a basis for decision-making for producers, further research is required on the potential role of these markets for producers to hedge against price risk.

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IDENTIFYING STRUCTURAL BREAKS

Over the past decades, the structure of the international coffee sector has changed substantially. To investigate possible change-points in the relationship between producer and futures prices, the method introduced by Gregory and Hansen (1996) will be employed. This residual-based test for cointegration between two markets allows for a regime shift and helps to identify an appropriate timeframe for the estimation. The underlying model is assumed to be

$$L_{ç}^{Ù} = ä + ñ L_{ç}^{ã} + A_{ç} \qquad (13)$$

where $L_{ç}^{Ù}$ and $L_{ç}^{ã}$ denote the futures price and producer price series, respectively, $ä$ and $ñ$ are parameters to be estimated, and $A_{ç}$ is the error term. In a cointegration setting, $ä$ and $Ù$ are assumed to be time-invariant. Yet under certain circumstances, they might be constant over a certain period and then shift to a new level. Such a shift might be modelled in a change in the intercept $ä$ and/or the slope $Ù$ To model such a change, it is helpful to introduce a dummy into equation (13):

$$î_{ç} = \begin{cases} 0 & E\ \mathrm{BP}Q\ ì \\ 1 & E\ \mathrm{BP}>\ ì \end{cases} \qquad (14)$$

where the unknown part $ì$ describes the timing of the structural break. Based on equation (1), Gregory and Hansen (1996) discuss different cases for the identification of a break date in this relationship.

$$L_{ç}^{Ù} = ä_5 + î_{ç}\, ä_6 + ñ L_{ç}^{ã} + A_{ç} \qquad (14a)$$

In this specification, only the intercept changes at a certain breakpoint. $ä_5$ is the intercept before the break date, $ä_6$ represents the change in the intercept after the shift.

$$L_{ç}^{Ù} = ä_5 + î_{ç}\, ä_6 + Ú\,\mathrm{P} + ñ L_{ç}^{ã} + A_{ç} \qquad (14b)$$

Again, only the intercept changes at the time of the break. The only difference between equations (14a) and (14b) is that the latter also includes a time trend.

$$L_{ç}^{Ù} = ä_5 + î_{ç}\, ä_6 + ñ_5 U_{6ç} + ñ_6 L_{ç}^{ã} î_{ç} + A_{ç} \qquad (14c)$$

Another structural break option allows the slope to also be different before and after the break. Again, $ä_5$ and $ä_6$ are the intercepts before and after the break date, respectively, $Ù_1$ denotes the slope before and $Ù_2$ the slope after the structural change.

$$L_ç^{Ù} = ä_5 + î_ç ä_6 + Ú Ᵽ Ú Ᵽ_ç + ñ_5 L_ç^{ã} + ñ_6 L_ç^{ã} î_ç + A_ç \qquad (14d)$$

In (14d), the structural change affects the intercept, the slope and the trend function. The ADF and the Phillips test statistics are then computed for all values of ì ó The most plausible breakpoint is given by the smallest value of the test statistics.

TESTING FOR COINTEGRATION

Following the definition given by Engel and Granger (1987), a time series which becomes stationary after differencing times is considered to be integrated of order denoted .
Two variables are considered cointegrated if both variables are integrated of the same order d and share a linear component which is stationary. The cointegrating relationship implies that the variables move closely together in the long run but may drift apart in the short run.

Different methods are available to test the order of integration of single time series. On the grounds of a method developed by Dickey and Fuller (1979), the Augmented Dickey-Fuller (ADF) test is one of the most widely used unit root tests. Following this approach, three different forms of the test can be used to test for the presence of a unit root:

$$\Delta y_t = \gamma y_{t-1} + \sum_{i=1}^{k} \beta_i \Delta y_{t-i} + \varepsilon_t \qquad (1a)$$

$$\Delta y_t = a_0 + \gamma y_{t-1} + \sum_{i=1}^{k} \beta_i \Delta y_{t-i} + \varepsilon_t \qquad (1b)$$

$$\Delta y_t = a_0 + \gamma y_{t-1} + a_2 t + \sum_{i=1}^{k} \beta_i \Delta y_{t-i} + \varepsilon_t \qquad (1c)$$

where k presents the number of lags chosen. Under the null hypothesis $\gamma = 0$, (1a) is a ‰µŒ Œ v }u Á olU ~í • and (1c) includes both constant and a linear time trend, $a_2 t$.

If two time series are found to be they can be tested for cointegration, i.e. whether or not there is a linear combination of the series which is covariance stationary. Following the procedure introduced by Johansen (1991), the null hypothesis of no cointegration will be tested against the alternative of one cointegrating vector. The Johansen approach has two different forms, the trace test and the maximum eigenvalue test. The former tests if the number of linear combinations equal a certain value against the alternative of being greater than .

Setting , the null hypothesis of the trace test is based on the assumption of no cointegration and needs to be rejected to establish cointegration between the variables. The test statistics are given by

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{n} \ln(1-\hat{\lambda}_i) \qquad (2)$$

The maximum eigenvalue test starts from the same null hypothesis, yet tests against a different alternative. The implication from rejecting the null hypothesis using the maximum eigenvalue is slightly different from the trace test. Though both forms are based on the assumption of no cointegration in their null hypothesis, rejecting the null based on the maximum eigenvalue implies that there is just a single possible combination of the non-stationary variables to yield in a stationary process. The corresponding test statistic for the maximum eigenvalue is given by

$$\lambda_{max}(r, r+1) = -T \ln(1-\hat{\lambda}_{r+1}). \qquad (3)$$

If the markets are found to be cointegrated, the Granger Representation Theorem (Engel and Granger, 1987) holds another important implication for their relationship: If two I(1) variables, e.g. two spatially separated markets (,)`, are cointegrated, their connection may be described by an Error Correction Model and vice versa. The Vector Error Correction Model (VECM) describing their relationship may be then written as follows:

$$\Delta p_t = \alpha(\beta' p_{t-1} + \mu + \rho t) + \sum_{i=1}^{k} \Gamma_i \Delta p_{t-i} + \gamma + \tau t + e_t \qquad (4)$$

where $\beta = (1, -\beta)'$ is the cointegration vector, z_t is the error correction term, i.e. the deviations from the long-run equilibrium of the two prices, and e_t are identically and independently distributed disturbances. The constant term μ in the adjusted model implies a linear time trend, and ρt a quadratic time trend in the price levels. The error correction vector α contains the parameters which measure the price series to deviations from equilibrium. The parameters are commonly called the error correction coefficients [illegible] determine the speed of the markets returning to equilibrium. The model has two parts: The long-run dynamics between the price series are presented in the first part, Ù ÚÑç?5 The second portion of the model, Ãþ Ü@5 #Ý¿;ç?Ý depicts the short-run dynamics of the relationship induced by market imperfections.

By allowing for a constant term and a time trend, the Johansen approach for fitting and estimating the model allows placing different restrictions on the trend terms, which result in five cases:

This case places no restrictions on the parameters and assumes a quadratic trend in the levels of the data. This means that the cointegrating equations are trend stationary, i.e. they are stationary around the time trend.

By setting ì = 0, the model allows for a linear, but not a quadratic time trend in the data levels. This restriction also allows the cointegrating equations to be trend stationary.

This specification poses the restrictions ì = 0 and é= 0 on equation (4). This excludes the possibility of the data levels to have a quadratic trend. It furthermore restricts the cointegrating equations to be stationary around constant means, but still includes a linear time trend in the levels of the data.

In this case, restrictions are posed such that ì = 0, é= 0 and Û= 0. This scenario excludes the quadratic and the linear time trend of the levels of data. Though specification allows levels to be stationary around a constant mean, it excludes any other trends and constant terms.

In the last specification, the model includes no nonzero means and trends anymore and places restrictions such that ì = 0, é= 0, Û= 0 and ä= 0. Here levels and differences of the data are assumed to have a zero mean, just like the cointegrating equations.

The different specifications allow for a greater flexibility in estimating the relationship of the two markets. This provides the possibility of selecting an appropriate model specification for each futures market/ country pair.

DETERMINING THE CONTRIBUTION OF MARKETS TO PRICE DISCOVERY

Based on the cointegration framework and the VECM introduced in Annex II, there are two widely used common factor models for investigating the principals of price discovery, the permanent-transitory (PT) model by Gonzalo and Granger (1995) and the information share (IS) criterion by Hasbrouck (1995).

Though the two models show similarities, they have different understandings of price discovery. The PT model is solely concerned with the error correction model and involves only permanent shocks (opposed to transitory ones) which result in disequilibria. The IS approach looks at the price discovery process with respect to the variance of innovations to the common factor. While the PT defines a market's contribution to price discovery as a function of the error correction coefficient and thus its part in the common factor, the IS looks at the market's relative contribution to the variance of the innovations. If $P_t = (p_t^f, p_t^p)'$, where p_t^f and p_t^p denote the futures price and the producer price, respectively, the two metrics start from the VECM as specified in (4),

$$\Delta P_t = \alpha(\beta' P_{t-1} - \mu) + \sum_{i=1}^{k-1} \Gamma_i \Delta P_{t-i} + e_t$$

with (k-1) being the lag order, $\beta = (1, -1)'$ being the cointegration vector, $z_t = \beta' P_t = p_t^f - p_t^p$ being the error correction term, α being a vector containing the error correction coefficient and e_t being a vector of serially uncorrelated residuals with zero mean and covariance matrix Ω such that

$$\Omega = \begin{pmatrix} \sigma_1^2 & \rho\sigma_1\sigma_2 \\ \rho\sigma_1\sigma_2 & \sigma_2^2 \end{pmatrix} \qquad (5)$$

The correlation between e_{t1} and e_{t2} is represented by ρ, σ_1^2 and σ_2^2 are the variances of e_{t1} and e_{t2}, respectively.

Stock and Watson (1988) show that if two price series are cointegrated, the vector P_t may be dissected into a common factor, representing the common effective price of the markets, and a transitory component. This leads to the model

$$P_t = Af_t + \tilde{P}_t \qquad (6)$$

where f_t denotes the common factor and $\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t})'$ is a vector containing the transitory components. Following Gonzalo and Granger (1995), the common factor f_t may be written as a linear combination of the variables X_t resulting in the model

$$f_t = \gamma_1 p_t^{1} + \gamma_2 p_t^{2} \tag{7}$$

The vector $\Gamma = (\gamma_1, \gamma_2)'$ is the vector of common factor coefficients, which may be viewed as the weights of each market in the common factor. Gonzalo and Granger (1995) also prove that the vector Γ is orthogonal to the vector of adjustment parameters α, implying in a binary case that $\alpha_1\gamma_1 + \alpha_2\gamma_2 = 0$. By posing a small additional restriction on the binary case so that the common factor weights sum up to unity, i.e. $\gamma_1 + \gamma_2 = 1$, and rearranging the two equations a little, it is easy to see that

$$\gamma_1 = \frac{\alpha_2}{\alpha_2 - \alpha_1} \qquad \gamma_2 = \frac{\alpha_1}{\alpha_1 - \alpha_2} \tag{8}$$

The decomposition of the common factor, i.e. the permanent influence on price changes, is the main idea of the PT model. Therefore, the two factor weights γ_1 and γ_2 present each market's contribution to price discovery.

The IS, however, measures each market's contribution to price discovery by decomposing the variance of the common factor innovations. Baillie et al. (2002) show the connection between the PT model and the IS approach by Hasbrouck (1995) and demonstrate that, if there does not occur a significant correlation between the error terms arising from the cointegration equation, the metric can easily be calculated by

$$IS_i = \frac{\gamma_i^2 \sigma_i^2}{\gamma_1^2\sigma_1^2 + \gamma_2^2\sigma_2^2} \tag{9}$$

Yet if there appears a significant correlation between the error terms, equation (13) does not hold. To eliminate the contemporaneous correlation, Hasbrouck (1995) employs a Cholesky factorization of $\Omega = MM'$, where M denotes a lower triangular matrix with the form

$$M = \begin{pmatrix} m_{11} & m_{12} \\ m_{21} & m_{22} \end{pmatrix} = \begin{pmatrix} \sigma_1 & 0 \\ \rho\sigma_2 & \sigma_2(1-\rho^2)^{1/2} \end{pmatrix} \tag{10}$$

By further noting that $IS_1 + IS_2 = 1$, the model can be rearranged to

$$IS_1 = \frac{(\psi_1 f_{11} + \psi_2 f_{21})^2}{(\psi_1 f_{11} + \psi_2 f_{21})^2 + (\psi_2 f_{22})^2} \tag{11}$$

$$IS_2 = \frac{(\psi_2 f_{22})^2}{(\psi_1 f_{11} + \psi_2 f_{21})^2 + (\psi_2 f_{22})^2} \tag{12}$$

The two equations (11) and (12) show that the computation of the IS only depends on the }Œ }ŒšZ}P}v oÀ ‰(But it also becomes clear that the factorization puts a larger weight on the first price series in the equation. This defines the upper (lower) bound of the information share of a market, depending on which market is first (second) in the factorization. Furthermore, the higher the correlation between the two markets, the greater (smaller) is the upper (lower) bound. Equations (11) and (12) show that the upper bound includes both the market's own contribution (ê represented by f_{11} in eq. (15)) and its correlation with the second market (é ê represented by f_{21}). The lower bound in comparison only includes only the market's uncorrelated contribution to the information share. It is also easy to see that the upper and lower of the IS depend on the magnitude of correlation, being larger (smaller), the higher the correlation between the two markets.