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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 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, while the futures prices comprise monthly averages of the `C´ futures prices from the Intercontinental Exchange in New York.

The econometric analysis of the price data confirms the existence of a stable long-run relationship between futures and producer prices. Cointegration could be found for futures and producer prices in all countries, which implies prices react to the same set of market information. Furthermore, past futures prices seem to influence both current futures and current producer prices in most cases. Past producer prices seem to have only limited influence on current futures levels.

The analysis of the role of the futures market as price discovery mechanism provided mixed results: 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). In Guatemala and Honduras however, the New York futures market indeed dominates price discovery, providing a useful basis for production and marketing decisions of coffee producers. Finally, the results for El Salvador are inconclusive due to limitations of the estimation method.

The study provides insight into the suitability of futures markets as a basis for decision making for producers. Further research and capacity building would be required to increase the ability of producers to use futures markets for hedging against price risk.

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[6] 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 foll(s)12 (p)-4 [illegible]

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

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 fut

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.

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 C			0	.	4

[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

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	¿LÖç	-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

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 in the Cholesky factorization, the two markets' contribution to the variance of innovations is almost equal. Yet if the producer price series enters into the equation first, the producer price series clearly dominates price discovery. The local market's larger share in price discovery might be connected to the fact that most Colombian coffee producers are members of FEDECAFE, which purchases coffee from its members at an internal price. This price is only based on the New York coffee `C´ futures price and also acts as a floor price in case members do not achieve higher prices from marketing their produce as specialty coffee (Gilbert and Gomez 2016). Furthermore, like Brazilian coffee, coffee from Colombia is not traded at par at the ICE. Colombian coffee is – contrary to coffee from Brazil – traded at a high premium, which may hamper the price discovery role of the futures market.

50. In Honduras and Guatemala, the futures market seems to be the primary source of price discovery. In Guatemala, about two-thirds of information is captured first by futures prices, while approximately one third is absorbed first by local producer prices. This is confirmed by both the PT and the IS model. In Honduras, the futures market plays an even bigger role in developing prices. Around 94% of new information is first taken up by the futures market, and only 6% by local producer prices. In this case, PT and IS give almost identical results, and the upper and lower bound of the IS are not very far apart. Coffee from both countries is traded at par in New York, possibly supporting the price discovery function of the futures market. The results are in line with the study conducted by Fortenbery and Zapata (2004), which already indicated a close relationship between the New York futures market and the two Latin American countries. The authors interpreted the relationship as a possibility for coffee market participants to hedge their price risk and the futures market serving as a centre of price discovery for Latin American exporting countries.

51. For the Dominican Republic, with respect to the PT model more than 97.5% of information is taken up first in the producer prices and only 2.5% by the futures prices. Following the IS approach, the futures market's share in price discovery gets close to 20%, yet price still seem to be primarily discovered in the local market. Looking at the bounds of the IS, one can see that, if producer prices are considered first in the Cholesky factorization, prices are entirely discovered in the local market. This might be connected to the fact that the country plays only a minor role in global coffee production and only a small fraction of its production is traded on the international market. This is supported by the study of Mattos (2004) that shows the relevance of trading volume in the relationship between futures and spot prices. The authors find that the price discovery

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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 terGzLN6Ah1MeL P@nd

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:

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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

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6 (NN) = Í ln(1 F ấ) (2)
Ü@å> 5

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

ãà ô ê (N, N+ 1) = F 6 H(1 F ấ). (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:

¿;ç = Ù(ÚÑ;ç? 5 + ä+ é) P+ Í #Ý¿;ç? Ý + Û+ ì P+ A dynamics between the price series are presented in the first part, Ù ÚÑ̃ç?5. The second portion of the model, Ã$^{Þ}_{Ü@5}$ #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),

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

with $\beta' = (1, -\beta_1)$ being the cointegration vector, $z_t = \beta' P_t = p_t^f - \beta p_t^p$ being the error correction term, α being a vector containing the error correction coefficient and e_t being a vector of serially uncorrelated innovations with 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 and 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

$$P_t = f_t + G_t \qquad (6)$$

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 p_t resulting in the model

$$f_t = \gamma_1 p_t^{S} + \gamma_2 p_t^{F} \tag{7}$$

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

$$IS_i = \frac{\gamma_i \sigma_i}{\gamma_1^2 \sigma_1^2 - \gamma_1^2 \sigma_1^2} \tag{9}$$

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

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

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

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 m_{11} in eq. (15)) and its correlation with the second market (é ê represented by m_{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.