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Explaining coffee price differentials in terms of chemical markers: Evidence from a pairwise approach☆

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ABSTRACT

We use time-series and cross-section methods to study long-term relationships between pairs of coffee prices, and assess how chemical, institutional and market factors affect the likelihood of finding stationary price differentials, the magnitude of such differentials, and their speed of adjustment. Using an empirical approach which does not require classifying coffee varieties as reference and non-reference, we find that varieties with chemical similarity have prices which are more similar, more likely to maintain stable long-term relationships, and more quickly to adjust after a shock.

1. Introduction

In many developing countries coffee, like other agricultural commodities, is an important source of foreign exchange, government revenue, employment, value added and, ultimately, economic growth; see e.g. Addison et al. (2016). Because of its importance, several authors have studied the dynamics of coffee prices using the four composite "indicator prices" constructed by the International Coffee Organization (ICO) in London.[1] For example, Vogelvang (1992) and Otero and Milas (2001) postulate and test hypotheses concerning the existence of long-run linear equilibrium relationships between the four indicator prices of coffee, and detect the existence of cointegration equations. Ghoshray (2009) estimates threshold models which support the view that the four ICO prices are highly integrated, and in a subsequent paper Ghoshray (2010) reports similar findings based on nonlinear unit root tests. Lastly, authors such as Enders and Holt (2012), Russell et al. (2012) and Ghoshray (2013) argue that to understand the dynamics of coffee prices in levels and measure their persistence, one must account for structural breaks.

An interesting feature that arises when comparing the prices of the two species of coffee, namely arabica coffee and robusta coffee, is that the former is usually more expensive than the latter. This is related to the organoleptic properties of arabica coffee, as it is usually perceived as having a milder taste than robusta coffee, and therefore seems more attractive to consumers. Also, as indicated by Smith (1985), even within arabica coffee differences in quality emerge depending on whether the coffee beans have been processed at origin by the washed (wet) method or by the unwashed (dry) method; coffee beans processed with the former are commonly referred to as milds, and tend to be more expensive than the ones processed with the latter; see Table 1.

While many studies have investigated the movements of coffee prices over time and in relation to each other, less attention has been paid to the differentials that exist between them, which in turn depend on the geographical origin of the beans, among other factors.

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[1] The "indicator prices" refer to the spot prices of four main groups conformed by similar kinds of coffee, namely unwashed arabicas (mostly coffee from Brazil), Colombian milds (mostly coffee from Colombia), other milds (mostly coffee from other Latin American countries), and robusta (mostly coffee from African and Asian countries).

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Table 1
Main characteristics of the coffee types under consideration.

Origin	Species (method)	Price	Chemical marker						*prod*	*inst*
			Δ^5_{ave}	*sit*	αtoc^g	βtoc^g	αtoc^r	βtoc^r		
Brazil	Arabica (unwashed)	109.65	3.10	2.41	3.06	8.68	2.62	7.79	0.34	1
Colombia	Arabica (washed)	138.16	2.85	2.01	2.69	7.85	2.47	6.44	0.10	1
El Salvador	Arabica (washed)	124.50	3.18	2.04	2.72	7.95	2.65	7.24	0.02	1
Guatemala	Arabica (washed)	129.29	2.37	1.51	2.43	7.45	2.16	7.17	0.05	1
Indonesia	Robusta	65.97	10.93	0.51	1.93	2.49	1.85	1.84	0.07	0
Mexico	Arabica (washed)	117.20	3.03	1.93	2.72	7.95	2.65	7.24	0.04	1
Peru	Arabica (washed)	122.83	3.03	1.93	2.72	7.95	2.65	7.24	0.02	1
Uganda	Robusta	71.90	10.80	0.80	1.54	2.00	1.38	1.46	0.03	1

Notes: Price (in US cents/lb) is the average price over the study period. The data on Δ^5avenasterol and sitostanol (*sit*) are taken from Table 2 in Carrera et al. (1998). These values represent the percentages of each sterol among the thirteen sterols listed in footnote 7. In some cases, Carrera et al. analysed several samples of coffee of the same origin, and so for each chemical substance we compute the country average. Furthermore, Carrera et al. do not analyse the chemical composition of coffee samples from Mexico and Peru, and so, as proxy, we use the average of Costa Rica and Honduras given that all these coffee types are regarded as belonging to the other milds category by the ICO. The data on αtoc^g, βtoc^g, αtoc^r, and βtoc^r (in mg/100g) come from Fig. 3 in Alves et al. (2009). For some countries Alves et al. analysed several samples of coffee of the same origin, and so, once again, for each chemical substance we compute the country average. Given that Alves et al. do not chemically analyse samples of coffee from Mexico, Peru and El Salvador, we use the average of Costa Rica, Honduras and Nicaragua, since they are all regarded as belonging to the other milds category by the ICO. Therefore, caution must be exercised when interpreting the results. The data on *prod* (in percentage) corresponds to the country share in world coffee production in the year 1998. These percentages were calculated using production information provided by the ICO. Farmer participation in market authorities of coffee exporting countries is denoted with the dummy variable *inst*, as taken from Appendix C in Coe (2006).

Oberthür et al. (2011), for instance, study environmental differences between coffee-growing areas in the departments of Cauca and Nariño in Colombia, and find significant differences in biochemical and sensorial product characteristics between the two departments, which provides support for the application of regionally-based denominations of origin. Donnet et al. (2008) study the price determinants in top-quality *e*-auctioned specialty coffees, and find that market clearing prices depend on sensory characteristics (quality rating by "expert jurors"), reputation (a variable that indicates whether a coffee variety came first, second, third, fourth, or lower than fourth place in cupping competitions), country of origin, coffee variety and quantity. Additional evidence on the effect of the country of origin on coffee prices can be found in Donnet et al. (2010), Teuber and Herrmann (2012) and Cerasa and Buscaglia (2017), among others.[2]

This paper proposes a study of price differentials for different coffee qualities with the aim of highlighting their dependence with respect to their chemical characteristics. More specifically, we are interested in testing three hypotheses concerned with whether the chemical composition of coffee types affects i.) the likelihood of finding stationary price differentials; ii.) the magnitude of these differentials; and iii.) their speed of adjustment. In all cases, we also allow for the potential effects of market and institutional drivers. We view the stationarity of coffee price differentials as an indicator of long-run price convergence based on a tendency for prices to not necessarily be equal, but instead move together over time. Therefore, this paper is not about explaining coffee price levels, but differentials. Our interest in coffee differential pricing is motivated by the Stigler and Sherwin (1985) definition of a market in terms of a product space defined by characteristics, instead of geographical separation. Indeed, according to Stigler and Sherwin, quality differences create price differences. Thus, in the specific case of coffee, arabica is of superior quality than robusta, and yet their prices tend to move together over time so that they may be thought of as belonging to the same market. In other words, our paper contributes to the debate about the conflicting views of a globally integrated coffee market, where competition guarantees that the effect of a shock in one part of the market propagates to other parts, as opposed to a market characterised by different geographical regions with diversified price behaviour.

The econometric modelling strategy that we adopt offers two distinguishing features with respect to the existing literature. The first feature is that we provide an explicit association between economics and chemistry. In economics our starting point is the concept of market, defined as that region or geographical area in which buyers and sellers interact in such a way that the prices of the same products tend to equality; see Cournot (1838) and Marshall (1920). Ever since Engle and Granger (1987), this notion of market has been tested by investigating whether prices maintain a stable long-run equilibrium relationship, such that discrepancies from this relationship do not show a systematic tendency to increase (or decrease) over time. Formally, this involves testing whether prices are cointegrated with cointegrating vector $[1, -1]'$.[3] Within this framework, we follow a pairwise approach advocated by Pesaran (2007a), which is based on the idea that for a given sample of N prices, one must conduct unit root tests on all $(N(N-1)/2)$ price differentials, and determine the ones that are stationary. Here it is worth highlighting that the pairwise approach, being based on the computation of all possible price differentials, offers the great advantage that it does not require the choice (in some cases arbitrary) of a benchmark or reference price with respect to which all other prices ought to be measured.[4]

As for chemistry, there are studies that have succeeded in discriminating between coffee types on the basis of the chemical composition of the beans. Alves et al. (2009) indicate that the chemical composition of coffee beans is influenced by climate conditions, agronomical practices, processing methods (dry versus wet), storage and distribution conditions, and roasting procedures. Consequently, in simple terms the specific hypotheses that we wish to test refer to the idea that coffee pairs that are more similar in chemical composition are also more similar in price. Notice that the innovative part of our analysis is that the chemical composition of coffee beans can be measured objectively. This is in sharp contrast with more traditional approaches in which prices are assumed to depend on quality ratings and rankings by "expert jurors", which are clearly subjective, or on dummy variables that represent the

[2] Perhaps the earliest work on the relation between quality and price is Waugh (1928), who studies the effects of physical characteristics such as size, shape, colour, maturity and uniformity, among others, on the prices of asparagus, tomatoes, and hothouse cucumbers.

[3] This condition is consistent with Definition 2.1 of stochastic convergence in Bernard and Durlauf (1995), who also consider a weaker form of convergence (in Definition 2.2) with cointegrating vector $[1, -a]'$; see Westerlund and Narayan (2013) for an illustration applied to the efficient market hypothesis in futures markets under conditional heteroskedasticity. Tests of the convergence hypothesis started with Baumol (1986), Barro (1991) and Barro and Sala-i-Martin (1992); see Narayan et al. (2011) for an application to stock market convergence.

[4] Although one could, for instance, apply Granger causality tests to determine "market leaders" and "followers", this status is not necessarily time invariant; see e.g. Wlazlowski et al. (2011) for the case of crude oil.