# Oligopoly in International Commodity Markets: The Case of Coffee Beans

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**Abstract**

This research aims to: (i) quantify how much market power was exercised by an international cartel with export quota arrangement, and (ii) separately identify the extent to which its breakdown and the emergence of an outside producer caused declines in the price. I analyze the market of coffee beans because it offers the cleanest case of such cartel agreements. I develop and estimate a structural model of collusion in the presence of an outsider. Counterfactual experiments suggest that, of the 75% price drop between 1988 and 2001, 49% points are attributed to the breakdown of the cartel, 9% points to the emergence of Vietnam as a major exporter, and the remaining 17% points to other shocks. Simulations also indicate that cross-border farmland M&A could materially raise the price. The results call for a better coordination of trade and competition policies with those of foreign aid and FDI.

## 1 Introduction

Despite caffeine, coffee can be depressing. Between 1988 and 2001, the price of coffee beans dropped by 75% to the 89-year low of 50 cents per pound.[1] Exporting countries and producers around the globe suffered the consequences.[2]

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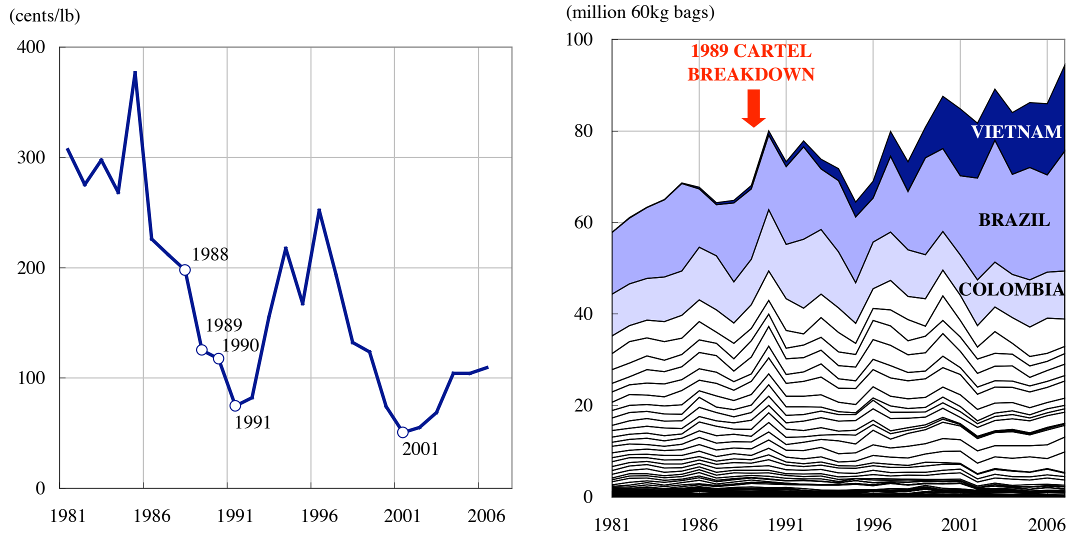
[1]Spot price (Brazilian and Other Arabica) at New York Board of Trade, adjusted by US-CPI to the 2007 constant US dollar. The 89-year low refers to the period since the beginning of my price data in 1913. With a longer time-series, it might turn out to be the lowest price in more than a century.

[2]Between 1988 and 1994, real GDP grew by only 0.96% annually in countries where the majority of exports is in coffee, while the figure is 3.19% for non-coffee exporters. The ensuing waves of sovereign debts cancellations cost over $162 billion to the taxpayers in richer countries (total debt relief for 51 coffee exporting countries, 1990-2007). In Colombia, the plight of the coffee industry fueled the intensifying violence (Dube and Vargas, 2008). In Rwanda, where 57% of all exports was coffee, the commodity crisis contributed to exacerbating ethnic conflicts and the subsequent humanitarian disasters. The coffee-growing states of Oaxaca and Chiapas are homes to many Mexican migrants in the US.




Source: Commodity Research Bureau (CRB), Bureau of Labor Statistics (BLS), United States Department of Agriculture (USDA), and Author's calculations.

Figure 1: Price and Exports of Coffee Beans

Episodes abound on crises due to dropping commodity prices. While the effects of commodity crises are well documented,[3] few studies have analyzed their causes. This gap partly reflects the common belief that commodity prices are volatile and therefore unpredictable. Not always so. Contrary to popular beliefs, cartel and imperfect competition are prevalent forms of market structure for many commodities traded in international exchanges.[4] Hence, changes in market power and competition can potentially explain price movements of these commodities.

I propose to explain one of the most prominent commodity crises in recent history: the coffee crisis. I concentrate on the coffee market for three reasons. First, the market saw typical rise and fall of a cartel arrangement, which employed one of the "cleanest" mechanisms through which to coordinate actions: export quota. Second, coffee is one of the most heavily traded commodities, second only to crude oil. Many of the characteristics present in this market are shared by those of other major exchange-traded commodities. Finally, given its role as a primary cash crop, the sector has macroeconomic implications to numerous developing countries.

I develop and estimate a model of a cartel and an outsider, to separately evaluate the impacts of the cartel breakdown and the emergence of Vietnam (Figure 1). The results suggest that, of the 75% drop in coffee prices between 1988 and 2001, the breakdown of

[3]See Deaton (1999), Catao and Sutton (2002), and Varangis *et al.* (2003), among others.

[4]For example, the OPEC controls a sizable proportion of the world's crude oil exports. The diamond market saw successful exercise of monopoly power by De Beers. Slade and Thille (2006) analyze cartel arrangements in the base metals markets (aluminum, copper, lead, nickel, tin, and zinc). Gilbert (1996) presents a historical assessment of the international commodity agreements on cocoa, coffee, rubber, sugar, and tin in the second half of the 20th century, while Stocking and Watkins (1946) document the prevalence of cartels in the markets of sugar, rubber, nitrogen, steel, aluminum, magnesium, and various chemical products in the first half of the century. Cartel and imperfect competition are rather the norm than exception in many commodity markets.

the cartel in 1989 is responsible for 49% points. The expansion of production in Vietnam and other supply/demand shocks explain further 9% points and 17% points, respectively. Because the first two factors were partly due to the trade and aid policies of the rich countries' governments, they were practically in control of the coffee crisis. In order to avoid costly, unintended consequences, therefore, competition and trade policies should be coordinated with that of foreign aid.[5]

Moreover, the model and its structural parameter estimates also allow for hypothetical commodity "booms" on the back of recent developments including: (i) the growing demand from China – one of the most important factors in the contemporary commodity markets – and (ii) a surge in cross-border acquisition of farmlands. Both of them should lead to commodity booms, but of different magnitudes. If the current level of low market power persists, even the doubling of the global demand (equivalent to a catch-up of the Chinese per-capita coffee consumption to the British or Japanese level) would not raise the price by more than 20% in the long run. However, with the cross-border M&A of farmlands (or a hypothetical "regional integration" of coffee-export policies), the coffee price could easily jump five-fold. The combination of both can potentially raise the price by twelve-fold. Thus, policies governing such forms of foreign direct investment are predicted to have material impact on the commodity market.

In section 2, I explain my empirical approach and related literature. Section 3 introduces the model, a hybrid of Cournot and Stackelberg games. Section 4 describes the construction of my dataset. Section 5 shows the estimation results. Counterfactual experiments in section 6 simulate worlds without the coffee crisis, to separately measure the effects of the cartel breakdown, the emergence of Vietnam, and other shocks. In section 7, scenarios of coffee booms are simulated to evaluate the likely price impacts of demand growth and cross-border M&A. Section 8 concludes with public policy implications.

## 2 Approach and Related Literature

My general strategy is to estimate coffee bean demand, and then use the estimates jointly with a model of supply side, to recover the effectiveness of the quota agreement, i.e., the degree of competition/collusion among countries except Vietnam, the new entrant. We can measure the impact of the cartel breakdown in 1989 by comparing the actual price after 1989 to the counterfactual with a functioning cartel. To separately identify the impact of the Vietnamese beans on the coffee price, the study exploits the fact that Vietnam started and expanded coffee production unilaterally, on the back of the foreign aids from the World

[5] A companion paper, Igami (2009), exploits these results to examine the responses of sovereign debt financing to the predictably permanent terms-of-trade shocks. A simple model of defaultable debt suggests that the level of sovereign debt financing should drop in the face of negative terms-of-trade shocks of permanent nature to borrowing countries. In data, however, private creditors' lending patterns do not appear to vary with debtors' coffee-dependence, in the five years following the shock (1989 through 1993). Eventual losses incurred by the lenders (or "haircuts") were significantly larger on heavily coffee-dependent debtors. Meanwhile, public-sector lenders increased capital flows to these countries, as if to pay for the consequences of the coffee crisis partially triggered by their own trade and foreign aid policies. Overall, the results point to the rooms for better coordination among competition/trade policies and foreign aid/sovereign financing policies.

Bank and the US-AID.

My approach builds on the industrial organization literature on the identification of the market power (Bresnahan 1982, Bresnahan 1989, Genesove and Mullin 1998). This paper is the first to apply such frameworks to international trade. Specifically, the study extends the scope of market power analysis to the internationally traded commodity as an industry, and to the export quota agreement as a form of collusion. I model and estimate the market power among the exporting countries (excluding Vietnam, the new entrant) as a structural parameter of the cartel agreement, upon which my counterfactual experiments are based.

Researchers have studied the economics of international cartels, including commodity agreements based on export quota. Since the coffee market presents one of the clearest cases, with huge welfare consequences, it has been the subject of intensive scrutiny (Mehta and Chavas 2008, Vogelvang 1992, Akiyama and Varangis 1990, among others). None of them, however, models market power in an explicitly oligopolistic framework.[6] This paper differs from those mentioned above in characterizing the international commodity cartel by a collusion model, and in measuring the extent to which changes in market power affected the price. Hence the main contribution of the paper is in clarifying the major role that market power plays in the markets of internationally traded commodities, and in highlighting its trade-, aid-, and FDI-policy implications.

# 3 Model: Cournot-in-Stackelberg

The framework of product market competition builds on Bresnahan (1982 and 1989). The primary difference is that I add a Stackelberg structure in modeling the relationship between Vietnam (outsider) and the traditional exporting countries' cartel. This setup allows for the interpretation of the market power parameter ($\theta$ in the following) as the structural parameter of the cartel's effectiveness.

For the traditional coffee exporters (i.e., all countries except Vietnam), consider $N$ firms (countries) producing homogeneous goods (coffee beans). Firm $i$ in period $t$ chooses output ($q_{it}$) to maximize its profit:

$$\pi_{it} = P_t\left(Q_t\right) q_{it} - C_{it}\left(q_{it}\right), \tag{1}$$

where $Q_t = \sum_i q_{it}$, $P_t\left(\cdot\right)$ is the inverse demand function, and $C_{it}\left(\cdot\right)$ is the cost function. On the supply side, there is the cost shifter $W_t$ that affects the marginal cost $mc_{it} = C'_{it}\left(q_{it}\right)$. The output price $P_t$ is determined by the demand $Q_t\left(P_t\right)$, which I specify in a linear form:

$$Q_t = \alpha_0 + \alpha_1 P_t + \alpha_2 X_t + \alpha_3 Z_t + \alpha_4 Z_t P_t + \varepsilon_t, \tag{2}$$

where $X_t$ is the demand shifter, $Z_t$ is the demand rotator, and $\varepsilon_t$ is the unobserved shock.[7]

[6] One exception is Karp and Perloff (1993), who model the coffee market as a dynamic duopoly of Brazil and Colombia. The estimation of a dynamic model is an attractive line of extension for the current study, but duopoly may not be an accurate characterization when the two countries' combined market share is only 39%, in the presence of 53 other exporters.

[7] The error term $\varepsilon_t$ is allowed to be serially correlated in my estimation of the standard errors. The potential concern over autocorrelation in the residuals receives full consideration in Appendix A. Moreover, in Appendix B, I also present demand estimates and all the empirical results based on the log-linear specifications.

Hence the inverse demand function is:

$$P_t(Q_t) = \frac{1}{\alpha_1 + \alpha_4 Z_t}\left[Q_t - (\alpha_0 + \alpha_2 X_t + \alpha_3 Z_t + \varepsilon_t)\right]. \tag{3}$$

The first order condition of firm $i$'s profit maximization is:

$$P_t + \frac{\partial P}{\partial Q}\theta_{it} q_{it} = mc_{it}, \tag{4}$$

where $\theta_{it} \equiv \left(1 + \frac{\partial \tilde{Q}_{-i,t}}{\partial q_{it}}\right)$ parameterizes firm $i$'s conjecture about the other firms' response to a change in its output. For a more intuitive interpretation of this parameter, we can also express $\theta_{it}$ as the elasticity-adjusted markup:

$$\theta_{it} = (P_t - mc_{it})\frac{-(\alpha_1 + \alpha_4 Z_t)}{q_{it}} = \begin{cases} Q_t/q_{it} & \text{if perfect collusion,} \\ 1 & \text{if Cournot competition,} \\ 0 & \text{if Bertrand/perfect competition.} \end{cases} \tag{5}$$

Since $\theta_{it}$s might vary across firms in reality and are therefore hard to interpret, I will instead estimate the average market power across the cartel members, $\theta_t$.[8] Using the cartel's total output, $Q_t = \sum_i q_{it}$, and their output-weighted average marginal cost, $\overline{mc_t}$, we have:

$$\theta_t = (P_t - \overline{mc_t})\frac{-(\alpha_1 + \alpha_4 Z_t)}{Q_t} = \begin{cases} 1 & \text{if perfect collusion,} \\ 1/N & \text{if } N\text{-firm Cournot competition,} \\ 0 & \text{if Bertrand/perfect competition.} \end{cases} \tag{6}$$

Vietnam emerged as a major coffee producer during the 1990s (Figure 2). Apparently, Vietnam's entry and expansion happened outside the quota agreement among the incumbent producers. I model Vietnam as a unilateral first-mover, in relation to the cartel of the traditional producers, because the move was greatly helped by the foreign aids, and cannot be viewed as a potential entrant's genuine response to the market conditions. The traditional coffee exporters, meanwhile, collectively respond as a cartel to Vietnam's output decision.[9]

To summarize the industry model, there are $N$ traditional exporters, each of whom chooses output $q_{it} \in [0, \infty)$ and receives profit $\pi_{it}$ defined in (1). Vietnam is the sole outsider. In each period $t$, the game proceeds as follows:

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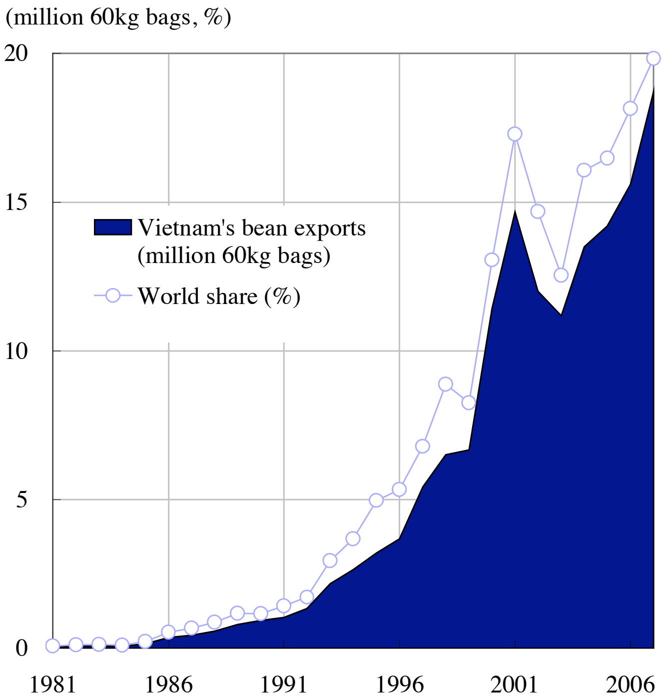
[8] Alternatively, it is called "conjectural variations" or "conduct parameters" in the literature. Corts (1999) criticizes this market power identification approach. His central concern is misspecification when some dynamic collusion is at play. In other words, the market power estimation rests upon a static conception of firm behavior. See Appendix C for the full discussion of this point and why the static representation of market power is likely to capture the cartel dynamics in the present case.

A systematic investigation into the exact functioning of the coffee cartel, possibly employing a repeated game framework, would be interesting. In this paper, however, I take my empirical analysis as a static approximation to what could have been happening in the coffee market competition. We can evaluate the usefulness of the model in light of industry characteristics, estimation results, and policy implications.

[9] Alternatively, Vietnam can be simply included as another cartel member, for modeling purposes. The results (estimates for the market power) does not change much because Vietnam's emergence came several years after the breakdown of the cartel. In order to interpret $\theta_t$ as a structural parameter of cooperation (collusion), it is conceptually more consistent to regard Vietnam as an outsider in relation to the cartel.




Source: USDA; Author's calculation.

Figure 2: The Vietnamese Expansion

1. Vietnam is endowed with some exogenously determined amount of coffee beans $\left(q_t^V\right)$, all of which it dumps on the international market;[10]

2. Knowing $q_t^V$ and the current world demand, the cartel of traditional exporters collectively decides how much to export $Q_t = \sum_i q_{it}$. In responding to Vietnam, however, the cartel cannot necessarily behave like a monolithic second-mover, as in a typical Stackelberg duopoly setting. That is because the tightness of collusion among the cartel members may not be perfect. Instead, the extent of coordination (market power), $\theta_t$, will be estimated from data.

3. Given the total output, $Q_t^{ALL} = q_t^V + Q_t$, the international price is determined by the inverse demand function, $P\left(Q_t^{ALL}\right)$. Each country receives payoff $\pi_{it}$ in (1).

Thus, the game is a tailored version of the Stackelberg competition, with Cournot structure embedded inside the second mover(s). The first mover, Vietnam, is non-strategic. The second mover, the cartel, contains in itself the Cournot-type strategic interactions among its members, whose degree of cooperation is characterized by the market-power parameter $\theta_t$.

[10]This simple setup reflects my characterization of the Vietnamese coffee production, during the early period of expansion, as follows: (i) Vietnam's production capacity is determined exogenously by the availability of arable lands and the amount of foreign aids to develop new farms; and (ii) Vietnam's marginal cost $(mc_{vt})$ is so low that it does not care how much the rest of the world will export or how much the Americans or Germans or Japanese will drink.

Three methodological caveats are in order. First, to focus on the cartel's market power and its changes, my model abstracts from product differentiation among coffee beans.[11] Although the prices of "different" beans follow each other quite closely (correlations are higher than .93), the results are indicative at best regarding highly differentiated brands such as Jamaican Blue Mountain or Hawaii Kona. Finer data would allow more sophisticated demand analysis in this direction.

Second, the characterization of exporting countries as "firms" ignore the interaction between governments, coffee farms (usually rural households), and other domestic players such as intermediaries, exporters, and bureaucrats. During most of the periods under study, national governments were indeed the single most important decision makers regarding production and exporting, with national coffee boards as coordination device. Nevertheless, institutional details at sub-national level might be potentially important, especially as a political-economy issue.[12]

Third, the current framework is static. Due to data availability, the analysis does not incorporate potentially interesting dynamics of inventory or capacity adjustment.[13] Likewise,

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[11] Coffee beans are commonly classified into the following four categories in the world's commodity exchanges: Colombian Mild Arabica, Other Mild Arabica, Brazilian Natural Arabica, and Robusta.

[12] Rich institutional details are provided by Bohman, Jarvis, and Barichello (1996) on the exporting countries' political economy, and by Bohman and Jarvis (1990) on the black market.

For the purpose of the current paper, let us note that the interpretation of the farm-gate prices as the marginal costs (of exports) retains consistency between the model and the reality as long as the exporting country's government: (i) behaved as the maximizer of the coffee producers' profits (as in the case of Colombia and other Latin American countries), (ii) acted as a benevolent social planner for the overall domestic economy, or (iii) is faced with a competitive domestic market for coffee beans.

A complicated case would arise when the government (iv) exploits its monopsony power to maximize its own rents, as in the case of some African countries. As a theoretical curiosity, market power in output market may actually rise when the government exercise monopsony power in domestic market. If we take domestic political economy seriously, however, such effects would then be confounded with the individualistic rent-seeking activities of bureaucrats and other industry insiders. I believe these issues are of secondary concern when the main focus of the analysis is on the overall market power of the cartel agreement across numerous exporting countries.

Finally, even if none of the convenient characterizations in (i) through (iii) held up, the presence of the black market, as documented by Bohman and Jarvis (1990), would still support my intepretation of the farm-gate prices as the marginal cost of exports. Specifically, there existed a competitive international "black" export market comprised by those importing countries that were *not* the members of the International Coffee Agreement, including the former "Eastern" bloc, Israel, and New Zealand. Together they accounted for roughly 5% of the global consumption. Since this market operated under no restriction, the prices were reportedly very close to the contemporary farm-gate prices in my dataset. Though small relative to the global output, this black market always provided a "safety valve," an alternative export destination for each exporting country. Hence, the black-market ($\approx$ farm-gate) price represents the opportunity cost (and marginal cost) of exporting beans to the "official" ICA market.

[13] Although green coffee beans are storable for some years, the actual level of inventory is very low relative to the quantity produced and consumed every year, in both exporting and importing countries. Interestingly, during the 1960s, Brazil seemed to hold a sizable amount of inventory (equivalent to a few year's harvest).

Capacity adjustment is an intriguing aspect of the industry. For the purpose of the current paper, however, capacity dynamics is of secondary importance, as long as the export quotas are exogenously fixed (as was actually the case in most occasions). This is because, faced with the fixed quota allocation, a country's optimal capacity roughly corresponds to that quota.

Specifically, because a country cannot (profitably) export more than its allocated quota in normal years, it is optimal to maintain capacity at that level. However, once every 5-10 years, a major frost/drought hits a systematic investigation into the exact functioning of the coffee cartel, possibly employing dynamic game frameworks (e.g., Ellison 1994, Fershtman and Pakes 2000, and Doraszelski and Pakes 2007), is also left for future extensions.[14]

# 4 Data: Price, Exports, and Marginal Costs

There are three sources of data on coffee beans. First, the price ($P_t$) of green coffee beans is provided by the Commodity Research Bureau (CRB). It is the average of the spot prices of the Brazilian and Other Arabica beans. Second, the US Department of Agriculture (USDA) collects data on the bean exports ($q_{it}$) from each of the 55 producing countries. Third, the International Coffee Organization (ICO) compiles data on the prices paid to the growers ($mc_{it}$, from the viewpoint of exporting intermediaries) in many producing countries.

The price data is monthly, while the exports and the farm prices are of annual frequency. Data on prices and exports are available from the 1950s and 1960s, respectively, but data on $mc_{it}$ starts from 1981.[15] Consequently, I estimate the demand function using data for 1960-2006, while the market power is estimated only for 1981-2006.

The supply shifter, $W_t$, is used as an instrument for $P_t$ in demand estimation.[16] For the supply of coffee beans, weather is the most important shock. I construct weather shock variables in the following manner. The trade publication *The CRB Commodity Yearbook* contains news on events that influence commodity prices, from which I collect the record of major frosts and droughts in producing countries, above all Brazil. Since it usually takes two years for damaged coffee trees to recover, I code "1" for 24 months starting from the month of a weather shock and "0" otherwise.[17]

In addition, from the demand estimation perspective, the rise and fall of the cartel arrangements represent additional source of price variation due to supply factors. Therefore, I exploit it by coding "1" for the months when the International Coffee Agreement (ICA) was in effect.[18] In total, two dummy variables comprise the supply-side shock vector $W_t$ for instrumenting $P_t$ in demand estimation. Because $P_t$ and $W_t$ are monthly series, they are annualized by taking market-yearly average (i.e., October to September, following the international coffee year), in order to match the data frequency of the other variables.

The profile of the fifty-five producing countries are as shown in Table 1.

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Brazil, leading to the temporary lift of the quota restrictions for all countries. To maximize the expected profit, therefore, a country would keep its capacity at the level slightly exceeding the quota just in case one of those "lucky" years arrives. The redundant beans are absorbed in the black market in normal years.

[14]See the second half of Appendix for potential demand- and supply-side dynamics, and Appendix C for further discussions on the cartel dynamics.

[15]The price series actually starts in 1913, but there is discontinuity in the early 1940s.

[16]Although in principle I can instrument $P_t$ by $\overline{mc_t}$, $W_t$ is preferable as IV because the farm-gate prices might occasionally reflect some demand shocks in actual data.

[17]The estimation results are robust to changes in the way I code the weather variable, including different treatments of the instances of multiple frost/drought shocks.

[18]The estimation results are robust to the inclusion/exclusion of this variable as well as its interaction term with weather variable.

Table 1: Coffee Exporters

| Rank | Country | Exports (million 60kg bags) | Share (%) | Rank | Country | Exports (million 60kg bags) | Share (%) |
|---|---|---|---|---|---|---|---|
| 1 | Brazil | 14.730 | 23.164 | 29 | Togo | 0.236 | 0.371 |
| 2 | Colombia | 10.102 | 15.886 | 30 | Cuba | 0.232 | 0.365 |
| 3 | Indonesia | 4.262 | 6.701 | 31 | Central African Republic | 0.227 | 0.357 |
| 4 | Cote d'Ivoire | 3.638 | 5.721 | 32 | Vietnam | 0.209 | 0.328 |
| 5 | Uganda | 2.724 | 4.284 | 33 | Sierra Leone | 0.140 | 0.220 |
| 6 | Mexico | 2.629 | 4.134 | 34 | Zimbabwe | 0.134 | 0.211 |
| 7 | El Salvador | 2.432 | 3.824 | 35 | Liberia | 0.126 | 0.198 |
| 8 | Guatemala | 2.304 | 3.623 | 36 | Venezuela, RB | 0.109 | 0.172 |
| 9 | Costa Rica | 1.737 | 2.731 | 37 | Bolivia | 0.106 | 0.167 |
| 10 | Cameroon | 1.634 | 2.569 | 38 | Panama | 0.092 | 0.144 |
| 11 | Kenya | 1.547 | 2.433 | 39 | Guinea | 0.069 | 0.108 |
| 12 | Ethiopia | 1.354 | 2.129 | 40 | Malaysia | 0.059 | 0.093 |
| 13 | Congo, Dem. Rep. | 1.315 | 2.067 | 41 | Paraguay | 0.055 | 0.087 |
| 14 | Ecuador | 1.281 | 2.015 | 42 | Lao PDR | 0.048 | 0.075 |
| 15 | India | 1.269 | 1.996 | 43 | Sri Lanka | 0.047 | 0.074 |
| 16 | Honduras | 1.167 | 1.835 | 44 | Yemen, Rep. | 0.046 | 0.072 |
| 17 | Peru | 0.951 | 1.495 | 45 | Benin | 0.034 | 0.053 |
| 18 | Madagascar | 0.891 | 1.402 | 46 | Malawi | 0.032 | 0.051 |
| 19 | Papua New Guinea | 0.843 | 1.325 | 47 | Congo, Rep. | 0.031 | 0.048 |
| 20 | Tanzania | 0.811 | 1.276 | 48 | Nigeria | 0.024 | 0.038 |
| 21 | Nicaragua | 0.727 | 1.144 | 49 | Gabon | 0.021 | 0.034 |
| 22 | Rwanda | 0.560 | 0.881 | 50 | Ghana | 0.016 | 0.026 |
| 23 | Dominican Republic | 0.540 | 0.848 | 51 | Trinidad and Tobago | 0.016 | 0.026 |
| 24 | Angola | 0.530 | 0.833 | 52 | Jamaica | 0.015 | 0.024 |
| 25 | Burundi | 0.486 | 0.764 | 53 | Equatorial Guinea | 0.008 | 0.013 |
| 26 | Philippines | 0.426 | 0.670 | 54 | Zambia | 0.003 | 0.005 |
| 27 | Haiti | 0.322 | 0.506 | 55 | Guyana | 0.002 | 0.003 |
| 28 | Thailand | 0.240 | 0.378 | | World | 63.591 | 100.000 |

Note: "Exports" are 1980-1988 average, i.e., before the cartel's breakdown and before Vietnam became a major producer. "Share" is the country's share in the world coffee bean exports.
Source: USDA; Author's calculation.

# 5 Estimation

If we know each firm's marginal cost over time ($mc_{it}$), we can estimate the price-elasticity of demand ($\hat{\alpha}_1$) and recover the market power parameter, $\hat{\theta}_{it}$. As I will describe in the next section, the data contains a reasonable proxy for $mc_{it}$, which allows us to take the simplest approach explained here.[19] First, I regress total output on price, which is instrumented by the supply shifters, and controls. Second, I recover the cartel's market power (or coordination) parameter from its output, marginal costs, and the price coefficient estimated in the first step.

[19] Alternatively, one can estimate the average market power parameter(s) $\hat{\theta}_i$ over certain periods, if one chooses not to use data on $mc_{it}$ and simultaneously estimate these marginal costs. All the unobserved components of marginal costs (such as user cost of capital and transport costs) will be automatically considered when I estimate economic marginal costs instead of relying on observed cost data. However, the marginal cost estimates tend to be imprecise. This is the reason I use data rather than estimates.

In the first step, I estimate demand parameters. The instrumental variable for $P_t$ is the supply shifter $W_t$, which, with (partial) $R^2$ ranging between .40 and .73, is not a "weak" instrument. Also, the p-values for the F-statistics comfortably range between 0.0000 and 0.0125.

Table 2 exhibits the demand estimates. The price coefficient ranges between $-35.44$ and $-58.43$. Columns [1] and [4] use only $P_t$ and a constant as regressors, while columns [2], [3], [5], and [6] include the demand shifter $X_t$ and the demand rotator $Z_t$.

Table 2: Demand Estimates

| | OLS | | | IV | | |
|---|---|---|---|---|---|---|
| Dep. var.: $Q_t$ | [1] | [2] | [3] | [4] | [5] | [6] |
| $P_t$ (Coffee price) | -58.43*** | -47.29*** | -35.44*** | -45.62* | -49.05*** | -29.68** |
| | (21.07) | (7.75) | (7.84) | (24.11) | (8.20) | (14.06) |
| $X_t$ (Buyers GDP) | | 28599*** | 34373*** | | 28784*** | 37396*** |
| | | (1131) | (4403) | | (912) | (5187) |
| $Z_t$ (Tea price) | | | 16.88 | | | 25.83* |
| | | | (11.63) | | | (14.73) |
| $Z_tP_t$ (Interaction) | | .0341*** | .0096 | | .0354*** | -.0055 |
| | | (.0093) | (.0132) | | (.0099) | (.0270) |
| Constant | 79371*** | -4137 | -27137 | 76542*** | -4423* | -38695* |
| | (6253) | (2625) | (16708) | (7697) | (2595) | (20126) |
| Adjusted $R^2$ | .37 | .92 | .92 | .35 | .92 | .92 |
| Number of observations | 47 | 47 | 47 | 47 | 47 | 47 |
| Shea's partial $R^2$ for $P_t$ | – | – | – | .52 | .73 | .40 |
| 1st-stage F-stat for $P_t$ | – | – | – | 6.93 | 11.01 | 15.69 |
| Shea's partial $R^2$ for $Z_tP_t$ | – | – | – | – | .71 | .30 |
| 1st-stage F-stat for $Z_tP_t$ | – | – | – | – | 3.64 | 10.92 |

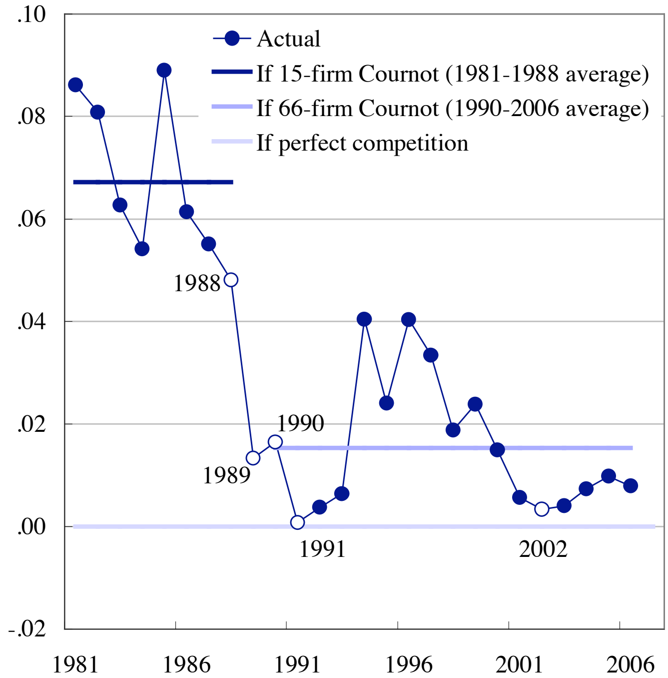
Note: ***, **, and * indicate significance at 1%, 5%, and 10% levels, respectively. Heteroskedasticity- and autocorrelation-consistent (up to 5 lags) standard errors are in parentheses. I chose 5-year lags as maximum because a new coffee tree needs three to five years to reach full production potential, but different lags (bandwidths) do not materially alter the HAC standard errors. $P_t$ and $Z_tP_t$ are instrumented by the coffee supply shifters (weather shocks) $W_t$ and their interaction with the tea price $Z_tW_t$. See Appendices A and B for the full results.

I use [5] as the baseline result in what follows because, given potential simultaneity biases on one hand and the strong IVs on the other, it is safer to use IV estimates. Among the IV estimates, [4] is too simple while the coefficient estimate for $Z_tP_t$ in [6] is insignificant.[20] The tables in Appendix show the full results, including log-linear specification and other combinations of regressors.

In the second step, I use equation (6) to invert out the implied market power of the cartel, $\hat{\theta}_t$. Figure 3 plots the evolution of $\hat{\theta}_t$ over time. It is reasonable to see huge declines between 1988 and 1990 because the export quota agreement came to a halt on July 4th, 1989.

The overall levels of the market power are fairly low. The measure should equal one

[20]The price coefficient of $-49.05$ in [5] implies the price-elasticity of demand (at mean price and quantity) of 0.174, which is lower than usual grocery food products at retail level. The lower elasticity is probably due to the fact that green bean costs account for only a small fraction of the final retail prices. In other words, green beans are physically essential but cost-wise negligible input for the final coffee products.




Note: Estimates of the average elasticity-adjusted markup ($\theta_t$) among coffee exporters excluding Vietnam. The number equals 1 under perfect collusion, 0 under perfect competition, and 1/N under N-firm symmetric Cournot competition.

Figure 3: Collusiveness among Traditional Exporters $\left(\hat{\theta}_t\right)$

($\hat{\theta}_t = 1$) if the cartel acts as a monolithic decision maker; $\hat{\theta}_t = 0$ if the member countries totally ignore the quota agreement and engage in perfect competition. The values in-between $\hat{\theta}_t \in (0,1)$ can be understood as competition levels equivalent to some Cournot competition among $\frac{1}{\theta}$ firms of symmetric size. If $\hat{\theta}_t = 0.33$, for example, the competition is as fierce as in a symmetric 3-firm Cournot game.

For the pre-breakdown period (1981-1988), the average is $\bar{\theta}_{pre} = 0.067$. This suggests the competition among the cartel members was as tough as in a 15-firm Cournot game. Hence the cartel was not very tightly managed. Given the fact that there were 55 exporting countries, however, the quota agreement was a moderate success. This is the key parameter estimate to be used in the counterfactual analysis in the next section.[21]

After the demise of the agreement (1990-2006), the average becomes as low as $\bar{\theta}_{post} = 0.015$. This implies 66-firm quantity competition, which roughly correspond to the actual

[21]An alternative explanation to the dropping coffee price might come from the demand side. Namely, a hike in the price-elasticity of demand would cause the equilibrium prices to fall.

Underlying stories behind such changes in demand would be: (i) the introduction of substitutes such as bottled water and caffeinated energy drinks; (ii) the price wars between Coca Cola and Pepsi since the 1990s lowered the cola prices, arguably a close substitute; (iii) growing "health-consciousness" deterred many consumers from drinking coffee; and (iv) the increasing fraction of the world's coffee drinkers now reside in emerging economies such as Brazil, Russia, India, or China. Each has some points, though not decisive in my view.

To determine the extent of changes in price-sensitivity, one can estimate the price coefficient of demand for separate periods. However, I found no significant change in the price coefficient across decades.

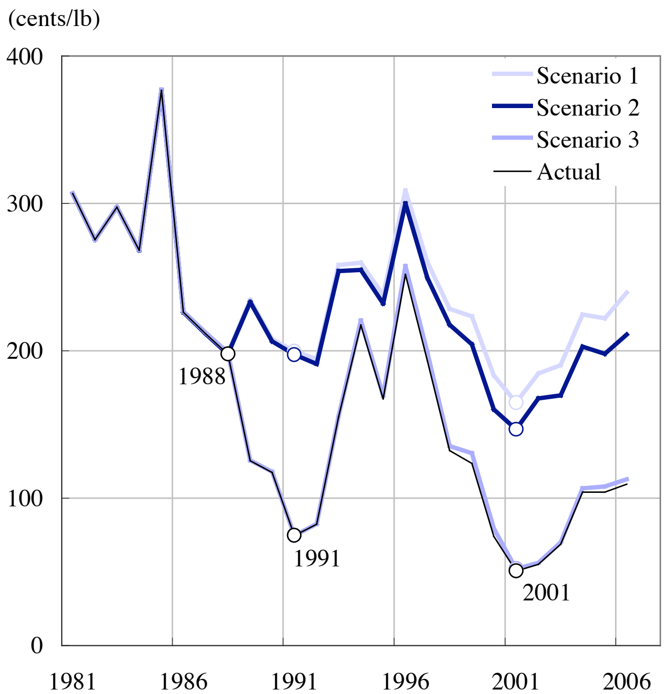
number of producing countries. Thus, the market power practically disappeared with the 1989 cartel breakdown. We can calculate the cartel effect, in terms of the market power parameter, as:

$$\bar{\theta}_{pre} - \bar{\theta}_{post} = 0.067 - 0.015 = 0.052.$$

# 6 Decomposing the Coffee Crisis (Simulation 1)

To determine the price effects of the 1989 cartel breakdown and the explosive growth of the Vietnamese exports, I simulate counterfactual prices. Specifically, I investigate three counterfactual scenarios as follows.

Scenario 1 is the "best-case scenario" for the traditional coffee exporters, based on the following setup: (i) the traditional exporters maintain the degree of collusiveness at 0.067 (1981-1988 average) even after 1988; and (ii) Vietnam's export is zero for all years. Scenario 2 assumes only (i), while Scenario 3 assumes only (ii). Needless to say, the actual history saw neither (i) nor (ii). Figure 4 displays the four price sequences.




Note: Scenario 1 is the best case based on (i) the traditional exporters maintain the degree of collusiveness at 0.066 (1981-1988 average) even after 1988, and (ii) zero export from Vietnam in all years. Scenario 2 assumes only (i). Scenario 3 assumes only (ii). The actual case saw both the cartel breakdown and Vietnam's export expansion.

Source: CRB; Author's calculation.

Figure 4: Counterfactual Prices

Let us take the year 2001, when the real coffee price hit the bottom. The actual price (per pound) $\left(P^A_{2001}\right)$ was 50¢, a 75% drop from the 1988 level of 198¢ $\left(P^A_{1988}\right)$:

$$\triangle P_{total} \equiv P^A_{1988} - P^A_{2001} = 148.$$

Table 3: Counterfactual Prices for Selected Years

| (cents/lb) | **Scenario 1** | **Scenario 2** | **Scenario 3** | **Actual Price** |
|---|---|---|---|---|
| *Cartel breakdown:* | No | No | Yes | Yes |
| *Vietnam's expansion:* | No | Yes | No | Yes |
| 1988 | 199 | 198 | 199 | 198 |
| 1991 | 200 | 197 | 75 | 75 |
| 2001 | 165 | 147 | 52 | 50 |

Source: CRB; Author's calculation.

In contrast, the best-case (Scenario 1) price in 2007 is 166¢ ($P^1$). The gap between $P^A_{1988}$ and $P^1$,

$$\triangle P_{shocks} \equiv P^A_{1988} - P^1 = 33,$$

is likely due to the combination of: (i) weather shocks to supply, (ii) income shocks to demand, (iii) substitution effects from changes in the tea price, and (iv) other unobservable shocks to supply and demand. These shocks together explain 17% points of the 75% total drop (or 21.6% of the 148¢ drop).

Scenario 2 adds Vietnam to the picture. Vietnam does not exist in Scenario 1, whereas in Scenario 2 Vietnam exports as much as it did in reality. The cartel responds to Vietnam's output in a relatively orderly manner, however, because the member countries are hypothesized to cooperate at the collusion level $\bar{\theta}_{pre} = 0.067$, not $\bar{\theta}_{post} = 0.015$. As a result, the price ($P^2$) is still respectable 147¢. We may call the gap between the $P^1$ and $P^2$ as the "Vietnam effect":

$$\triangle P_{viet} \equiv P^1 - P^2 = 18.$$

The Vietnam effect explains 9% points of the 75% total drop (or 12.2% of the 148¢ drop). Scenario 3 is the opposite of Scenario 2. Here the cartel brakes down in 1989, but there is Vietnam. With $P^3$ at 52¢, the price is remarkably lower than in the previous two scenarios. The gap between $P^2$ and $P^3$,

$$\triangle P_{cbd} \equiv P^2 - P^3 = 95.$$

can be labeled as the "cartel breakdown effect." $P^3$ is almost identical to the actual price in 2001, $P^A_{2001}$. With the cooperation level at $\bar{\theta}_{post} = 0.015$, the former cartel members compete (as selfishly as in a simple Cournot game) against each other, so the hole left by the absence of Vietnam is quickly filled by aggressive supply increases from everybody else. This is because outputs are strategic substitutes in a quantity competition. If Vietnam cuts down its export, the rest of the world increases it. The gap between $P^3$ and $P^A_{2001}$ can be understood as the interaction of the Vietnam and the cartel breakdown effects, i.e.,

$$\triangle P_{int} \equiv P^3 - P^A_{2001} = 2.$$

Taken together, the cartel breakdown effect and the interaction effect amount to 97¢, accounting for 49% points of the 75% drop (or 65.5% of the 148¢ drop). The overall price decline is therefore decomposed into:[22]

$$\begin{aligned}\triangle P_{total} &= \triangle P_{shocks} + \triangle P_{viet} + \triangle P_{cbd} + \triangle P_{int}, \text{ or} \\ 148 &= 33 + 18 + 95 + 2.\end{aligned}$$

Thus, the combined effects of the 1989 cartel breakdown and the emergence of Vietnam (as of 2001) can explain most of the coffee crisis.

# 7 When China Drinks Coffee and Brazil Grabs Africa (Simulation 2)

This section extends the scope of counterfactual experiments to: (i) global demand growth, (ii) increased market power, and (iii) the combination of both.

Commodity booms (and busts) in recent years have attracted attentions to the growing demand from emerging economies for all kinds of primary commodities including coffee. The consumption level of coffee in China is currently equivalent to about one cup per person *per year.* The corresponding figures for the UK, Japan, the US, Germany, and Finland are 1.01cups, 1.42 cups, 1.75 cups, 2.55 cups, and 5.33 cups per capita *per day.*[23] Although history may not necessarily repeat itself, judging from the speed at which Starbucks Coffee can expand its operations in Shanghai, for example, it may not be out of order to hypothetically consider a world where the global demand for coffee is doubled.

Table 4: Counterfactual Prices for Selected Years (II)

| (cents/lb) | **Actual Price** | **Scenario 4** | **Scenario 5** | **Scenario 6** | **Scenario 7** | **Scenario 8** |
|---|---|---|---|---|---|---|
| *China drinks coffee* | No | Yes | No | No | Yes | Yes |
| *Cross-border M&A* | No | No | Regional | Global | Regional | Global |
| 1998 | 132 | 132 | 132 | 132 | 132 | 132 |
| 2001 | 50 | 64 | 460 | 879 | 1,069 | 2,096 |
| 2006 | 109 | 131 | 556 | 1,016 | 1,262 | 2,429 |

Source: CRB; Author's calculation.

*Scenario 4* tries to capture the price effect of this doubled demand, by hypothetically cutting the price-coefficient of demand by half, for 1999 and afterwards. The prices in 2001 and 2006 would be 28% and 20% higher than the actual prices, respectively. Still, the doubled demand would not nearly compensate for the lost market power, as embodied in *Scenario 1* and *Scenario 2*, in terms of price. This is because, with negligible market power

[22] This is not the only way to decompose the effects. For example, if we start from the actual price in 2001 as reference point, we might as well characterize $\triangle P_{viet}$ as the interaction term, and $\triangle P_{int}$ as pure Vietnam effect. My point is just to demonstrate that the combined effects of these changes in competition explains much of the total price drop.

[23] According to the 2005 surveys conducted by the International Coffee Organization (available online).

at $\bar{\theta}_{post} = 0.015$, coffee exporting countries are behaving quite competitively, to the extent that a lower price-elasticity of demand is largely left unexploited.[24]

To push the market-power viewpoint further, one can consider "merger simulations" as another set of counterfactual experiments. Although the unit of analysis in this paper is countries, not companies, it is not totally unrealistic to imagine something analogous to mergers and acquisitions. The euro and the European Central Bank, for instance, present a successful case of regionally integrated monetary policies. Likewise, let us suppose coffee export policies are harmonized at regional levels: Latin America and the Caribbean (20 countries), Asia (10 countries), and Africa (25 countries). If the output decisions are made at this level, market power will rise to $\theta = 0.33$ (equivalent to symmetric 3-firm Cournot competition). This is the assumption underlying *Scenario 5*. The effect will be spectacular, with the price in 2006 surging five-fold to 556c/lb, even in the presence of Vietnam as an outsider producer.

What if $\theta = 1$, equivalent to the perfect collusion (monopoly) level? This is the case of globally integrated coffee supply decision making. Recent years have seen an increasing number of foreign land acquisitions such as South Korean wheat projects in Sudan, India's investment in Ethiopia, or Kuwaiti rice deals with Cambodia.[25] *Scenario 6* experiments with such an idea and assume $\theta = 1$ from 1999 onwards. The coffee price now approaches ten dollars per pound. Hence, it would make a profitable use of Brazil's sovereign wealth funds to buy out coffee farms in poor countries, and then reduce the global output to monopoly level. Alternatively, foreign aid can be used to buy influence in other producers' export policies.

Finally, *Scenario 7* and *Scenario 8* combine the demand- and supply-side counterfactuals, by supposing the doubled demand and regionally or globally integrated supply decisions. Now that the lower demand elasticity is exploited by the increased market power, the prices in 2006 would be 12- and 22-fold higher, respectively.

All the counterfactual scenarios in this section reflect radical thought experiments, but the results inform us not to be surprised by wild fluctuations in commodity prices when those factors are at play. Thus, in the face of the growing demand, public policies governing such forms of FDI can potentially impact the commodity market in a significant way.

# 8 Conclusion

The findings of this paper are as follows. First, the international cartel of coffee exporters achieved moderate but significant level of collusive pricing. It was moderate because the effective level of cooperation (or market power) was far from the monopoly level; it was

[24] This experiment is for illustration purpose only. In reality, it would be impossible to double the supply instantaneously, mainly because of the availability of land in suitable climate zones and also because new coffee trees require 4-6 years to reach full production capacity. However, one can still interpret the results as an indication of likely outcomes in the long-run, given certain levels of market power.

[25] The International Food Policy Research Institute (*cit. in. The Economist*, May 23rd, 2009) calculates that between 15m and 20m hectares of farmland in developing countries have been negotiated in deals involving foreigners since 2006, equivalent to about a fifth of all the farmland of the European Union, worth up to $30 billion.

significant in the sense that over 50 countries managed to achieve an outcome as collusive as in a 15-player quantity competition.

Second, the counterfactual experiments suggest that, of the 75% drop in the price of coffee between 1988 and 2001, 49% points are attributed to the disappearance of market power (the breakdown of the cartel in 1989), 9% points are explained by the emergence of Vietnam as a major exporter, while the remaining 17% points are due to other shocks such as weather and income.

These results reveal that, contrary to the conventional characterization of commodity markets as perfect competition, economic forces of oligopoly are fully at play. It is not just coffee: the markets of crude oil, diamond, base metals, and tropical agriculturals are also known for cartels and imperfect competition (Slade and Thille 2006, Gilbert 1996), to name a few. Therefore, economic analysis of the commodity markets should explicitly incorporate their oligopolistic industry structures in order to make inference from and predictions on the market outcomes.

As for policy implications, the study points to the potential for cross-fertilization between competition, international trade, and foreign aid policies, on three fronts. First, foreign aid can be an effective antitrust tool in countering international cartels. When the World Bank and the US government funded the development of coffee farming in Vietnam, the aim was to encourage farmers to substitute away from cultivating black-market crops such as heroine poppies. As a byproduct, this aid policy effectively reduced the market power of the traditional coffee exporting countries.

Alternatively, market power can be used as a lever for development assistance. In the case of the coffee export cartel, a big importing country like the US could help the enforcement of the quota agreement. Hence, international trade and competition policies can play the role of foreign aids.[26]

Third, it is important to explicitly acknowledge the above relationships between competition/trade policies and development aids. The US assistance to Vietnam was, presumably, not meant to punish Brazil, fuel violence in Colombia, boost Mexican migration to the US, trigger misery in Rwanda, or waste taxpayers' money on defaulted sovereign debts: unintended consequences. The study calls for better coordination among different divisions of public policies. Specifically, the assessment of product-market impacts should be an integral part of foreign aid design process.[27] In other words, when you give to the poor, *do* let your left hand know what your right hand is doing.

The simulation experiments also suggest that the combination of growing demand and the cross-border farmland M&A may cause prices to skyrocket. Whether to foster or block such deals is up to the governments' policy goals, but policymakers should be aware of the connections between competition, trade, FDI, and aid policies.

Finally, as an extension of the current analysis, it will be fruitful to employ explicitly

[26] Somewhat differently, "fair trade" schemes also enhance the market power of commodity producers by artificially creating rooms for product differentiation, another source of market power.

[27] Afghanistan can easily become another example of unintended consequences. On one hand, economic development of the country is often discussed in the context of the US defense strategy to pacify the region. On the other hand, the country produces over 80% of the global heroine supply. Hence crop substitution programs might seem like a solution on both fronts. However, if Afghanistan starts exporting, say, cotton, that will potentially destabilize its neighbors, Pakistan and India, who are major exporters of the commodity.

dynamic framework of competition and collusion. Provided that corresponding data are available, the producers' intertemporal decisions – capacity adjustment, inventory, and (endogenous) cartel agreements – can be fully investigated.[28]

[28] See Appendix C for full discussion.

## Appendix A: Checks for Autocorrelation

The baseline demand estimation attempts to correct for the residual's autocorrelation only with respect to standard errors. Here I display more comprehensive checks and corrections for the autocorrelation.

Table 5: Checks for Autocorrelation (Linear Specification)

| Dep. var.: $Q_t$ | OLS | | | | | |
|---|---|---|---|---|---|---|
| | [1] | [2] | [3] | [4] | [5] | [6] |
| $P_t$ (Coffee price) | -58.43*** | -88.85*** | -22.02*** | -29.97*** | -47.29*** | -35.44*** |
| | (15.18) | (14.93) | (5.52) | (5.39) | (11.33) | (13.19) |
| $X_t$ (ln Buyers' GDP) | | | 26421*** | 35681*** | 28599*** | 34373*** |
| | | | (1518) | (3548) | (1354) | (4405) |
| $Z_t$ (Tea price) | | -70.95*** | | 21.30*** | | 16.88 |
| | | (4.69) | | (7.60) | | (11.02) |
| $Z_tP_t$ (Interaction) | | .1199*** | | | .0341*** | .0096 |
| | | (.0182) | | | (.0124) | (.0187) |
| Constant | 79371*** | 104380*** | 173 | -32751*** | -4137 | -27137 |
| | (3789) | (3046) | (4584) | (12424) | (3664) | (16631) |
| Durbin-Watson d-stat | .44 | 1.33 | 1.84 | 2.22 | 2.10 | 2.22 |
| Box-Ljung Q-stat | 102.14 | 30.03 | 24.50 | 33.25 | 29.79 | 33.49 |
| p-value | .00 | .09 | .27 | .04 | .10 | .04 |
| Dep. var.: $Q_t$ | IV | | | | | |
| | [7] | [8] | [9] | [10] | [11] | [12] |
| $P_t$ (Coffee price) | -60.52*** | -99.55*** | -29.96*** | -31.91*** | -46.97*** | -27.62 |
| | (15.25) | (18.66) | (5.75) | (5.53) | (11.46) | (20.05) |
| $X_t$ (ln Buyers' GDP) | | | 25008*** | 36122*** | 28414*** | 37417*** |
| | | | (1474) | (3521) | (1341) | (6239) |
| $Z_t$ (Tea price) | | -71.84*** | | 22.80*** | | 26.42 |
| | | (6.52) | | (7.33) | | (17.96) |
| $Z_tP_t$ (Interaction) | | .1350*** | | | .0319** | -.0081 |
| | | (.0303) | | | (.0148) | (.0364) |
| Constant | 79515*** | 105010*** | 5701 | -34177*** | -3488 | -39263 |
| | (4321) | (3503) | (4580) | (12308) | (3546) | (24637) |
| Durbin-Watson d-stat | .46 | 1.34 | 1.89 | 2.25 | 2.11 | 2.25 |
| Box-Ljung Q-stat | 98.92 | 26.55 | 27.42 | 34.42 | 29.62 | 33.51 |
| p-value | .00 | .19 | .16 | .03 | .10 | .04 |

Note: ***, **, and * indicate significance at 1%, 5%, and 10% levels, respectively. Heteroskedasticity-robust standard errors are in parentheses. $P_t$ and $Z_tP_t$ are instrumented by the coffee supply shifters (weather shocks) $W_t$ and their interaction with the tea price $Z_tW_t$.

In order to see if there are concerns for serial correlation in the first place, Table 5 shows the two tests for the autocorrelation in the residual. Durbin-Watson's d-statistics value should fall in the range of $[0, 4]$, with values "far" from 2 indicating the presence of autocorrelation. The p-value is for the chi-squared test based on Box-Ljung's Q-statistics, with values less than .05 commonly take as the evidence of autocorrelation.

The results suggest that the specifications in columns [3], [5], [9], and [11] do not suffer from autocorrelation in the residuals. It seems the inclusion of $X_t$ (log of the consumer countries' GDP) ameliorates the serial correlation issues, by eliminating a time trend from the $Q_t$ (export quantity) series.

Still, I can try correcting for what autocorrelation that might exist, by explicitly including the lagged dependent variable ($Q_{t-1}$) in the right-hand side. The results, displayed in Table 6, further confirm that my baseline demand estimates (hence all the subsequent empirical results) are robust to the handling of autocorrelation.

Table 6: With Lagged Dependent Variable (Linear Specification)

| Dep. var.: $Q_t$ | OLS | | | | | |
|---|---|---|---|---|---|---|
| | [1] | [2] | [3] | [4] | [5] | [6] |
| $Q_{t-1}$ (Lag) | .8717*** | .5717*** | .1781 | .0612 | .0352 | .0474 |
| | (.0590) | (.1285) | (.1534) | (.1448) | (.1743) | (.1645) |
| $P_t$ (Coffee price) | -10.45** | -34.02** | -18.57*** | -28.87*** | -45.79*** | -33.24* |
| | (4.67) | (14.63) | (5.58) | (6.50) | (14.90) | (16.96) |
| $X_t$ (ln Buyers' GDP) | | | 21847*** | 33673*** | 27535*** | 33178*** |
| | | | (4695) | (6351) | (5586) | (6281) |
| $Z_t$ (Tea price) | | -27.93*** | | 20.80** | | 17.77 |
| | | (10.34) | | (8.28) | | (11.51) |
| $Z_tP_t$ (Interaction) | | .0412** | | | .0329** | .0071 |
| | | (.0195) | | | (.0152) | (.0217) |
| Constant | 11936*** | 44568*** | 72 | -31325** | -3746 | -27578 |
| | (4276) | (13096) | (4956) | (13324) | (4448) | (16899) |
| Box-Ljung Q-stat | 37.47 | 24.88 | 26.94 | 33.73 | 29.57 | 33.51 |
| p-value | .01 | .25 | .17 | .04 | .10 | .04 |
| Dep. var.: $Q_t$ | IV | | | | | |
| | [7] | [8] | [9] | [10] | [11] | [12] |
| $Q_{t-1}$ (Lag) | .8763*** | .5479*** | .0706 | .0187 | .0245 | .0316 |
| | (.0645) | (.1894) | (.1965) | (.1925) | (.2063) | (.1952) |
| $P_t$ (Coffee price) | -9.76 | -42.40 | -27.68*** | -32.29*** | -45.32*** | -22.30 |
| | (7.96) | (26.41) | (8.36) | (9.33) | (17.08) | (23.99) |
| $X_t$ (ln Buyers' GDP) | | | 23364*** | 35665*** | 27613*** | 37966*** |
| | | | (5340) | (8076) | (6474) | (7798) |
| $Z_t$ (Tea price) | | -28.80* | | 23.48** | | 31.82* |
| | | (16.88) | | (9.30) | | (17.82) |
| $Z_tP_t$ (Interaction) | | .0506 | | | .0302* | -.0182 |
| | | (.0398) | | | (.0182) | (.0380) |
| Constant | 11202** | 47063** | 4997 | -34359** | -3103 | -45218* |
| | (5577) | (21009) | (5328) | (14570) | (4252) | (24270) |
| Box-Ljung Q-stat | 37.83 | 23.50 | 26.97 | 33.71 | 29.23 | 32.65 |
| p-value | .01 | .32 | .17 | .04 | .11 | .05 |

Note: ***, **, and * indicate significance at 1%, 5%, and 10% levels, respectively. Heteroskedasticity-robust standard errors are in parentheses. $P_t$ and $Z_tP_t$ are instrumented by the coffee supply shifters (weather shocks) $W_t$ and their interaction with the tea price $Z_tW_t$.

Specifically, the coefficient estimates for $Q_{t-1}$ (lag) are not significantly different from zero in the models [3] through [6] and [9] through [12]. The p-values for the Box-Ljung test are also comfortably above .05 in columns [2], [3], [5], [8], [9], and [11]. Moreover, the price coefficient estimates are almost identical to the original results in Table 7 for at least [3], [5], [9], and [11]. Therefore it seems fair to conclude that the baseline demand estimates are not sensitive to the way I address (or not address) the autocorrelation issues.

Finally, it is interesting to consider potential reasons for the persistence in $\{Q_t\}$ over time, even though my baseline case does not exhibit such issues. One factor may be the addictive nature of coffee consumption, which would give rise to a sticky demand over time through habit-formation dynamics. Historically speaking, however, the per-capita consumption in the largest coffee importing country, the US, has long plateaued and not grown much since the 1960s. Although Americans "discovered" coffee houses in the 1990s, with the chain store operations proliferating into the 2000s, the phenomena merely changed the composition and location of coffee consumption in some subtle ways.

In contrast, less developed countries (in the past) are more likely to have experienced the increasing caffeine addiction during the sample period. However, simply controlling for GDP – i.e., income and population growth combined – seems enough to capture any habit-formation effect. Perhaps the pure "addiction effect" would be difficult to separate from the "income effect" when both factors work in the same direction during the same period of time.

On the supply side, potential "stickiness" factors include the gradual evolution of production capacity (including planting and growing of coffee trees, and construction of transportation infrastructure) and the inventory/storage adjustment at various stages of the supply chain, in both exporting and importing countries (although the extent of storage seems limited, as explained at the end of Section 2). However, these types of "investment" dynamics would not play major roles unless there are major unexpected shocks. The reason is, as long as the rigid quota regime is in place (as was actually the case), each producing country has little incentive to engage in wild investment activities. Hence the only occasions where time-to-build and inventory stickiness would matter are the times in which frosts and droughts of once-in-a-century magnitude hit Brazil's coffee producing regions. Such events are, by definition, rare, and are not likely to drive dynamics in my dataset over the entire sample period.

In summary, these are the potential factors that are likely to generate persistence effects in $\{Q_t\}$. Since my baseline models do not exhibit such autocorrelation in the residuals, however, I also suggested the possible reasons why those (suspected) stickiness factors are absent in my dataset and empirical results.

## Appendix B: Demand Estimates (Full Results)

The full results of the demand estimation is shown below. Column [11] of Table 7 is the baseline in the main text. The price coefficient of -49.05 implies the price-elasticity of demand (at mean price and quantity) of 0.174, which is broadly consistent with the estimates under the log-linear specification in Table 8 as well as those in the previous literature. For example, the log-linear estimates of column [1], [5], and [7] in Table 8 imply the elasticities of 0.25, 0.123, and 0.131, respectively.[29]

Table 7: Demand Estimates (Linear Specification)

| Dep. var.: $Q_t$ | OLS | | | | | |
|---|---|---|---|---|---|---|
| | [1] | [2] | [3] | [4] | [5] | [6] |
| $P_t$ (Coffee price) | -58.43*** | -88.85*** | -22.02*** | -29.97*** | -47.29*** | -35.44*** |
| | (21.07) | (13.35) | (3.60) | (4.07) | (7.75) | (7.84) |
| $X_t$ (ln Buyers' GDP) | | | 26421*** | 35681*** | 28599*** | 34373*** |
| | | | (1654) | (3285) | (1131) | (4403) |
| $Z_t$ (Tea price) | | -70.95*** | | 21.30*** | | 16.88 |
| | | (6.26) | | (7.43) | | (11.63) |
| $Z_tP_t$ (Interaction) | | .1199*** | | | .0341*** | .0096 |
| | | (.0183) | | | (.0093) | (.0132) |
| Constant | 79371*** | 104380*** | 173 | -32751*** | -4137 | -27137 |
| | (6252) | (3939) | (4447) | (11460) | (2625) | (16708) |
| Adjusted $R^2$ | .37 | .84 | .91 | .92 | .92 | .92 |
| Num. obs. | 47 | 47 | 47 | 47 | 47 | 47 |
| Dep. var.: $Q_t$ | IV | | | | | |
| | [7] | [8] | [9] | [10] | [11] | [12] |
| $P_t$ (Coffee price) | -45.62* | -96.94*** | -30.11*** | -31.92*** | -49.05*** | -29.68** |
| | (24.11) | (15.91) | (6.00) | (4.00) | (8.20) | (14.06) |
| $X_t$ (ln Buyers' GDP) | | | 24716*** | 36135*** | 28785*** | 37396*** |
| | | | (1493) | (2789) | (912) | (5187) |
| $Z_t$ (Tea price) | | -72.86*** | | 22.84*** | | 25.83* |
| | | (6.25) | | (5.54) | | (14.73) |
| $Z_tP_t$ (Interaction) | | .1399*** | | | .0354*** | -.0055 |
| | | (.0253) | | | (.0099) | (.0270) |
| Constant | 76542*** | 104468*** | 6353 | -34233*** | -4423* | -38695* |
| | (7697) | (3211) | (4773) | (9432) | (2595) | (20126) |
| Adjusted $R^2$ | .35 | .83 | .90 | .92 | .92 | .92 |
| Num. obs. | 47 | 47 | 47 | 47 | 47 | 47 |
| Shea's partial $R^2$ for $P_t$ | .52 | .67 | .50 | .62 | .73 | .40 |
| 1st-stage F stat for $P_t$ | 6.93 | 22.67 | 7.02 | 24.26 | 11.01 | 15.69 |
| Shea's partial $R^2$ for $Z_tP_t$ | – | .57 | – | – | .71 | .30 |
| 1st-stage F stat for $Z_tP_t$ | – | 9.66 | – | – | 3.64 | 10.92 |

Note: ***, **, and * indicate significance at 1%, 5%, and 10% levels, respectively. Heteroskedasticity- and autocorrelation-consistent (up to 5 lags) standard errors are in parentheses. I chose 5-year lags as maximum because a new coffee tree needs three to five years to reach full production potential, but different lags (bandwidths) do not materially alter the HAC standard errors. $P_t$ and $Z_tP_t$ are instrumented by the coffee supply shifters (weather shocks) $W_t$ and their interaction with the tea price $Z_tW_t$.

[29] As Genesove and Mullin (1998) summarize, the two functional forms can be derived from the same general demand curve $Q(P) = \beta(\alpha - P)^{\gamma}$. The linear case is when $\gamma = 1$, while the log-linear form corresponds to $\alpha = 0$ and $\gamma < 0$. So they are not just two ad-hoc choices by the analyst.

Table 8: Demand Estimates (Log-Linear Specification)

| Dep. var.: $\ln Q_t$ | OLS | | | | | |
|---|---|---|---|---|---|---|
| | [1] | [2] | [3] | [4] | [5] | [6] |
| $\ln P_t$ (Coffee price) | -.2500*** | -.5881** | -.0767*** | -.0919*** | -.1231* | .3778*** |
| | (.0407) | (.2623) | (.0132) | (.0163) | (.0717) | (.1129) |
| $\ln X_t$ (Buyers GDP) | | | .4004*** | .4613*** | .4297*** | .5351*** |
| | | | (.0163) | (.0632) | (.0523) | (.0541) |
| $\ln Z_t$ (Tea price) | | -.8825*** | | .0714 | | .5871*** |
| | | (.2318) | | (.0685) | | (.1598) |
| $\ln Z_t \ln P_t$ (Interaction) | | .0948** | | | .0066 | -.0821*** |
| | | (.0437) | | | (.0109) | (.0205) |
| Constant | 12.39*** | 16.46*** | 10.40*** | 9.891*** | 10.36*** | 6.735*** |
| | (.1960) | (1.355) | (.1025) | (.5516) | (.1573) | (1.012) |
| Adjusted $R^2$ | .51 | .83 | .92 | .93 | .92 | .93 |
| Num. obs. | 47 | 47 | 47 | 47 | 47 | 47 |
| Dep. var.: $\ln Q_t$ | IV | | | | | |
| | [7] | [8] | [9] | [10] | [11] | [12] |
| $\ln P_t$ (Coffee price) | -.1311** | -1.0479*** | -.0782*** | -.0907*** | -.0526 | .5080* |
| | (.0650) | (.3419) | (.0142) | (.0190) | (.0585) | (.2784) |
| $\ln X_t$ (Buyers GDP) | | | .3990*** | .4625*** | .3844*** | .5570*** |
| | | | (.0156) | (.0628) | (.0407) | (.0697) |
| $\ln Z_t$ (Tea price) | | -1.3058*** | | .0718 | | .7157** |
| | | (.3121) | | (.0708) | | (.3369) |
| $\ln Z_t \ln P_t$ (Interaction) | | .1736*** | | | -.0037 | -.1038** |
| | | (.0586) | | | (.0083) | (.0501) |
| Constant | 11.76*** | 18.91*** | 10.42*** | 9.879*** | 10.44*** | 5.91*** |
| | (.3704) | (1.807) | (.1090) | (.5372) | (.1275) | (2.06) |
| Adjusted $R^2$ | .39 | .83 | .92 | .93 | .92 | .93 |
| Num. obs. | 47 | 47 | 47 | 47 | 47 | 47 |
| Shea's partial $R^2$ for $P_t$ | .61 | .53 | .68 | .63 | .67 | .35 |
| 1st-stage F stat for $P_t$ | 9.14 | 32.37 | 25.14 | 43.31 | 17.96 | 36.27 |
| Shea's partial $R^2$ for $Z_tP_t$ | – | .53 | – | – | .66 | .34 |
| 1st-stage F stat for $Z_tP_t$ | – | 37.23 | – | – | 11.64 | 43.62 |

Note: ***, **, and * indicate significance at 1%, 5%, and 10% levels, respectively. Heteroskedasticity- and autocorrelation-consistent (up to 5 lags) standard errors are in parentheses. I chose 5-year lags as maximum because a new coffee tree needs three to five years to reach full production potential, but different lags (bandwidths) do not materially alter the HAC standard errors. $lnP_t$ and $lnZ_tlnP_t$ are instrumented by the coffee supply shifters (weather shocks) $W_t$ and their interaction with the tea price $ln(Z_t)W_t$.

In order to assess how the main findings vary under the log-linear specification, in Figure 5, I compare the empirical results based on the linear and log-linear demand specifications in three aspects: (i) the market power parameter estimates $\left\{\hat{\theta}_t\right\}$, (ii) the simulated cartel exports $\left\{\tilde{Q}_t\right\}$, and (iii) the counterfactual prices $\left\{\tilde{P}_t\right\}$.

First, the market power parameter estimates $\left\{\hat{\theta}_t\right\}$ retain the main qualitative feature: the market power dropped in 1989. However, the extent of drop is smaller in the log-linear case. The immediate cause of this discrepancy is as follows: $\hat{\theta}_t^L = -\frac{dQ}{dP}\frac{P_t - mc_t}{Q_t}$ in the linear case, while $\hat{\theta}_t^{LL} = -\frac{d\log Q}{d\log P}\frac{P_t - mc_t}{P_t}$ in the log-linear case. Hence, as $P_t$ drops, $\hat{\theta}_t^L$ will drop a lot (because the numerator decreases while the denominator increases), explaining a larger fraction of the variation in $P_t$. Meanwhile, $\hat{\theta}_t^{LL}$ will not drop much (because both the numerator and the denominator decrease), accounting for only a small fraction of the price fluctuation. This difference between $\hat{\theta}_t^{L}$ and $\hat{\theta}_t^{LL}$ also foreshadows the diverging results in the price simulations discussed below.

Second, the cartel's simulated export quantities (under different scenarios) are almost identical between the linear and log-linear cases. Third, even though the simulated prices are derived from those similar export quantities, the price sequences based on the log-linear demand is much more volatile than those based on the linear demand.

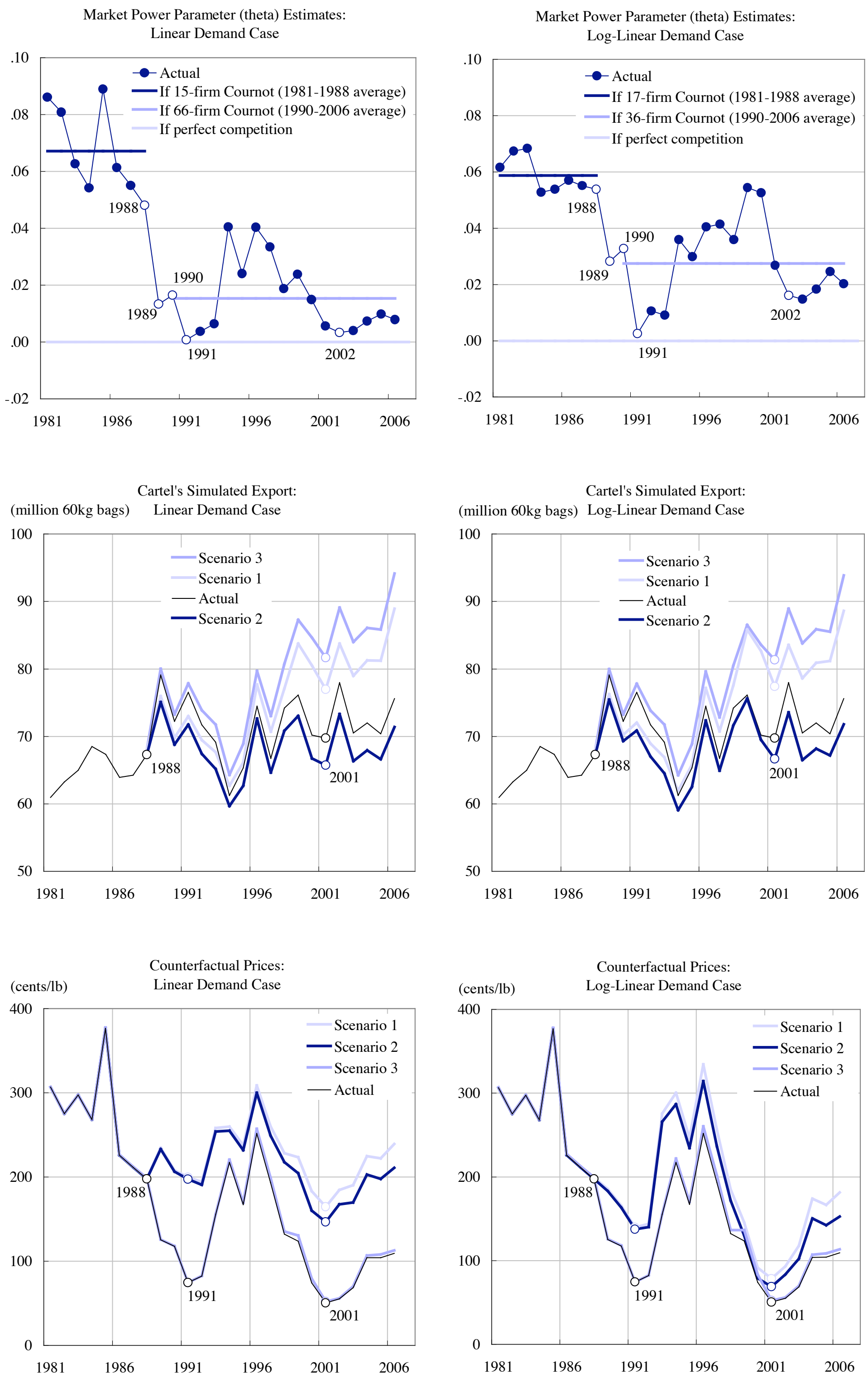
This outcome is driven by the fact that, under the log-linear demand specification, the price-elasticity of demand is confined to stay constant across different quantity levels. It follows that, in a high-volume region (as in the years after the mid-1990s), even a wide quantity variation will correspond to only a small change in price. Hence, even though export quantity varies a lot across different counterfactual scenarios, the resultant prices do not differ much from the Actual price series.

Consequently, the 75% drop in the price between 1988 and 2001 is decomposed differently under the log-linear specification: 10% points due to the cartel's breakdown and 5% points due to Vietnam's expansion. The remaining 60% points are attributed to miscellaneous (or "residual") factors, which is reminiscent of the low explanatory power given to $\hat{\theta}_t^{LL}$, as explained above.

I view the results based on the log-linear demand as a mathematical artifact, rather than an intrinsic economic insight, for two reasons. One is that the log-linear demand curve is not very realistic in the high-volume (or, equivalently, low-price) region when the nature of coffee demand is considered. While the constant-elasticity assumption (inherent in this specification) dictates that the world's coffee lovers drink ever more cups of coffee as the price goes down, there is actually a physical limit to how much one can drink. This observation casts doubt on the price simulations for the period after the mid-1990s, when the market was experiencing high volumes and low prices. The linear demand curve is the preferred model for this region.

The other reason to doubt the meaningfulness of the price simulations (based on the log-linear specification) is the excessively prominent role played by the "residual" factors. Because the 1988-2001 price fall was the largest in almost a century, with the bottom price at a new low, it is simply not believable that mere "residuals" could explain most of it when all the conceivable economic forces – the demise of the cartel, the expansion of Vietnam, the weather shocks, the consumers' income and population, and the tea price. Especially so in the coffee beans market, which is famous among investors and traders for being amenable to simple economic analysis of supply and demand.

Having cast doubts on the log-linear results, however, I find it reassuring that all the discrepancies between the linear and the log-linear cases are clearly attributable to the latter's mathematical properties, leaving no mystery. It is also encouraging to find that the relative importance of the two effects under investigation – the cartel's market power and the emergence of the new producer – is not significantly altered between the two specifications, i.e., the breakdown of the cartel had a somewhat bigger effect on the coffee price, while Vietnam's rise was also a non-negligible factor.




Source: CRB, BLS, USDA, and Author's calculations.

Figure 5: Estimates and Simulation based on Linear/Log-Linear Demand

## Appendix C: Underlying Dynamics of the Coffee Cartel

Although my model abstracts from the dynamic games that are potentially played inside the cartel (and with potential entrants), it would be helpful to consider the nature of these games. I can conceive three different types of such collusion dynamics. Still, for reasons stated below, the static notion of market power and the price-cost margin in my dataset are likely to capture the bottomline of these possible dynamic games in the case of the coffee beans market. Hence it is my view that the (static) market-power parameter can be interpreted as a logically consistent reduced-form representation of the collusion dynamics, in the institutional context under study.

### Case 1. Collusion is explicit (and exogenously enforced)

An exporting country cannot deviate much from its allocated quota because the importing countries monitor and enforce quota agreement. This seems to be the case in the actual functioning of the International Coffee Agreement, where the US government played the key role. It follows that what one sees through the static market-power model (i.e., the price-cost margin) is exactly what is actually happening. That is, the Agreement supported the specific level of market power (markup) in the estimate. Hence, any inherent cartel dynamics collapses to the static model.

### Case 2. Collusion is tacit (and endogenously enforced)

Theoretical literature studies this case extensively. To maintain the collusive price level in the repeated game context, each exporting country must be willing to "cooperate" rather than "defect" in each period. In principle, there can be an infinite number of different cartel arrangements built on complicated "punishment" actions (to be taken by the cartel members when someone defects). In practice, tacit agreements cannot be too complicated.

Given the actual industry configuration of the coffee beans market, the most conceivable punishment action would be for Brazil, the largest exporter, to "dump" its stocked beans into the international market for a certain number of periods, thereby lowering the price to the extent that no country would find it profitable to produce (and much less export) any beans. Although, historically speaking, even Brazil did not keep such a large inventory, such punishment strategies can support the collusive outcome consistent with my estimated $\hat{\theta}_t$ as a Markov-Perfect Equilibrium (or a Subgame-Perfect Equilibrium more generally).

Interestingly, the standard prediction from the theories of collusion is that, a tacit collusion, if successful, should never see an actual episode of defection and ensuing punishment. This is because the whole point of a severe punishment is not to actually hurt everyone's profit, but to underwrite the desirable level of cooperation by means of threat.

Thus, the (successful) outcome of a tacit collusion will be a sequence of prices that are consistently above the competitive level: observationally equivalent to what comes out of a static model. Hence, again, the cartel dynamics collapses to the static model, empirically.

### Case 3. Tacit collusion with capacity-based quota allocation

Hypothetically, the more interesting case of the cartel dynamics would be that of tacit collusion with endogenous quota allocation mechanism. A theoretical/computational model is studied by de Roos (2004). An intriguing feature is that, because future quota will be proportional to the members' capacities at the time of an agreement, a forward-looking member has an incentive to build up large capacity today (ignoring the negative consequences of price wars and low profit), in order to secure a richer quota allocation tomorrow (if the agreement is actually reached, that is).

This is model is believable in some industries. De Roos motivates this model by the actual episodes from the international lysine cartel. ADM, a new entrant, first engaged in capacity building and price war, and then struck a favorable quota deal with the incumbent firms. In principle, it is possible to picture some coffee-cartel members engaging in this kind of opportunistic behavior, such as Costa Rica planting "just a little bit more" trees in the hope of stealing future quota from Guatemala, say. There is in fact some evidence that the quota negotiation was sometimes bitter, with East African countries blaming Central Americans, who in turn attacked Colombia, who in turn battled with Brazil, and so on.

However, the final outcome of all these interactions anyway add up to the price-cost margin in the data, which I then translate in to the market-power parameter, $\hat{\theta}$, in a straightforward manner. The estimated $\hat{\theta}$ is reasonably persistent over time, especially during the cartel period. Hence, for all its interesting strategic implications, internal struggles over quota allocation is the storm in a cup, rather than any fundamental force that defined the shape and size of the cup (i.e., the overall level of collusiveness). It could be that such internal politics prevented the price from further rising. But it could also be that the importing countries supported only so much of supra-competitive margins.

### Static Notion of Market Power Likely Captures the Cartel Dynamics

From these considerations of dynamics, I view my static parameter of market power, $\theta$, as a logically consistent "reduced-form" representation of all the possible dynamic interactions at play. Observationally, I believe the price-cost margin (and the resultant market-power parameter) to be about as much as one can hope to infer from data, in a realistic attempt to measure the extent of competition in the context of coffee beans market.

This is not to deny the importance of oligopoly dynamics. To study the delicate dynamic incentives in this market, however, one has to be willing to make bold assumptions about the exact functioning of the cartel, which may or may not be borne out by data. And, regardless of the tacit forces and dynamic incentives behind the scene, the final outcome will always be what we already see in data: markup (and the market-power parameter).

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