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APPLICATION OF A DYNAMIC PANEL DATA ESTIMATOR TO CROSS-COUNTRY COFFEE DEMAND: A TALE OF TWO ERAS

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We estimate price and income elasticities of demand for green coffee beans in panels of up to 40 countries, both during and after the operation of export quotas under International Coffee Agreements. The dynamic panel estimator proposed in Han and Phillips (2007) is used because it is a consistent estimator, for any length of panel, regardless of the presence of unit roots. Dynamic panel data models, of any type, do not seem to have been previously applied to coffee demand. We find evidence of a concave relationship between income and coffee consumption for countries which are members of the International Coffee Organization, but no evidence of such a relationship for other countries. A further conclusion is that measures which increase the price of coffee beans can be expected to have little effect on coffee sales.

Keywords: Coffee Demand, Dynamic Panel Data, International Coffee Organization
JEL classification: C23, F53, O13, O57, Q11

1. INTRODUCTION

Coffee production is vital for the livelihoods of approximately 20 million families in more than 50 developing countries (Lewin *et al.* (2004)), Understanding the drivers of demand for green coffee beans, in terms of both price and income elasticities at the national level, is of great importance in making decisions which affect the development of coffee growing regions throughout the world. While dynamic panel data models are ideal for such analysis, they have not previously been applied in this field. Through ultilising these techniques, specifically the estimator proposed in Han and Phillips (2007), we are able to further explore issues examined in research from the last three decades in a robust modern framework.

Changes in consumption, incomes and prices over the period of our analysis are shown in Figure 1.

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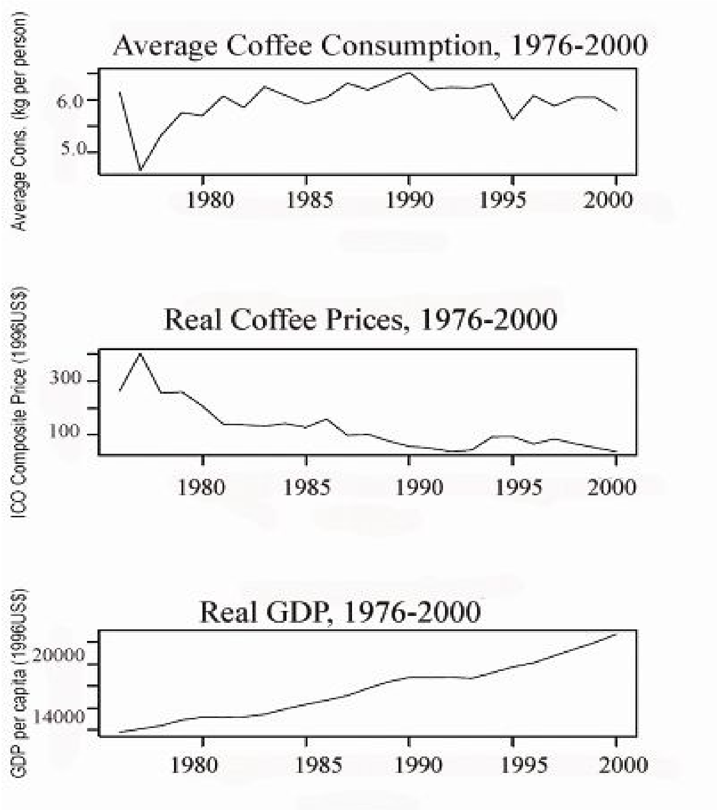

Figure 1. Coffee Consumption, Prices and Average Real GDP of Importing Members

The plan of this paper is as follows. Section 2 describes the history of export quotas and explains how their operation divides our period into two 'eras'. In section 3, we review previous literature. Section 4 sets out the econometric theory underpinning the estimator applied and presents key underlying assumptions. The data, models and methodology are discussed in section 5. Section 6 presents empirical results while section 7 concludes.

2. HISTORY OF EXPORT QUOTAS IN COFFEE MARKETS

Our period covers two eras: those during and after the operation of export quotas under the International Coffee Agreements (ICAs). Between 1962 and 1989 coffee prices were influenced by ICAs which formed the International Coffee Organization

(ICO) as an administrative body.[1] The cornerstone of the ICAs was the use of export quotas. These were based on a 15-day moving average of the ICO composite indicator price. There were six "trigger prices" for imposing or relaxing quotas (Gilbert (1996)).[2] The quotas were initially effective for two reasons. First, almost all exporting countries were members of the ICA; this meant that quotas were not undone by increased exports from non-member countries. Second, countries accounting for the majority of world coffee importers were also members, who agreed to only import from members and abide by the export quotas.[3] However, this was undermined by the fact that exports to non-members were unlimited, and hence often at a significant discount and were in some instances covertly re-exported to importing members.[4]

ICA quotas ceased in July 1989. Gilbert (1996) canvasses factors leading to the break down of this system and concludes that ultimately it collapsed because of a lack of clear consensus for its continuation. This fundamental change in the market in 1989 interrupts the time series data available, increasing the usefulness of panel data techniques. Because we consider panels both before and after 1989, we can compare and contrast the operation of the coffee bean market in the two eras.

3. REVIEW OF EARLIER LITERATURE

Most recent applied econometric work has been time series in nature and confined to developed countries. Two of the earliest papers are Akiyama and Duncan (1982) and Herrman (1986). Akiyama and Duncan (1982) use aggregated annual data over the intervals 1963-1979 and 1965-1979 to estimate price and income elasticities for net per capita coffee imports in nine regions. Herrmann (1986) estimates an aggregate world demand function that is log linear in price and (lagged) income levels. The estimated price elasticity is -0.27.

More recently the time series techniques developed over the 1980s and 1990s have been applied to the world coffee market. Most of these papers (such as, Lord (1991), Vogelvang (1992), Mehta and Chavas (2006)) focus on the behaviour of prices.

[1] See Gilbert (1996). The ICO is still in existence today, although its functions are considerably narrower (see www.ico.org).

[2] The implementation of quotas raised revenue of exporters because coffee is relatively price inelastic. An international agreement was necessary to achieve these gains because otherwise each exporting country would find it individually optimal to increase their exports despite the fact the overall welfare of coffee exporters is reduced in this Nash equilibrium (a classic prisoners dilemma).

[3] The consensus at the time was that the participation of importing members was motivated by development and foreign policy objectives (Kravis (1968)).

[4] For a discussion of this see Kravis (1968), Herrmann (1986) and Gilbert (1996). Estimates of the size of this discount are commonly in the range of 30-50% (Gilbert (1996)).

However, Olekalns and Bardsley (1996) is pertinent for our purposes. They estimate a rational addiction model for United States coffee consumption with annual data over the period 1967-1992. The addiction premise is perhaps one of the first economic theoretic justifications for a dynamic model of coffee demand. We utilise a dynamic model on the basis that coffee consumption is likely to be affected by habit and thus previous consumption can help explain current consumption. Dynamic models have been applied to demand for many other consumer goods, including cigarettes. (See, for instance, Brown (1952) and Becker *et al.* (1994).)

Applied industrial organisation research of coffee markets has been undertaken in recent years. This work has been motivated by the concerns about the exercise of market power raised in papers such as Talbot (1997) and Ponte (2002). These papers which include Bettendorf and Verboven (2000), Feuerstein (2002) and Durevall (2006) all find no significant evidence of the exercise of market power in the European countries that they investigate. As part of their investigation these papers estimated demand specifications. These provide useful benchmarks for our research. Bettendorf and Verboven (2000) utilise both linear and logarithmic demand specifications and the implied price elasticity from their results is -0.2 in all specifications. Feuerstein (2002) estimates the demand for coffee in Germany 1962-1989. Unable to reject a null hypothesis of non stationarity, Feuerstein imposed a unit root and took first differences. For a model which is log linear in income and prices the price and income elasticities obtained are -0.18 and 0.57 respectively. Durevall (2006) estimates a long run linear demand function. Durevall also includes a demographic variable (the ratio of those 15 years and older born before 1960). The stated rationale for his specification is "simplicity" and Durevall notes that most demand functions in this area are either linear or log linear. It is interesting to note the use of two intervals (during and after the era of quotas) in Durevall's analysis. We also believe that the use of such intervals is prudent.

This summary reveals a dearth of panel data analysis despite the benefits that it can offer through adding cross-sectional variation whilst controlling for individual effects. The application of dynamic panel data techniques provides the opportunity to explore some of the issues raised in a more robust framework. Moreover, we believe that the novel use of a quadratic specification implying a concave relationship between income and coffee demand is appropriate because demand can be expected to increase with income but will ultimately satiate; there are only so many cups of coffee that people wish to consume in a day.

4. ESTIMATION TECHNIQUE

This paper applies the dynamic panel data estimator recently proposed by Han and Phillips (2007). This estimator is well suited for cross country panels with a moderate cross-sectional and time-series dimension and where regressors (in this case price and GDP) may evolve according to a unit root process. The Han and Phillips (2007) estimator is based on a linear transformation which avoids the inconsistency present in fixed effects estimation of dynamic panel models that was first identified in Nickell (1981). It is special in that it is consistent even when the autoregressive coefficient approaches unity. The estimator requires that errors are white noise, and that $n \cdot T \to \infty$. This last property suits our panels which have a moderate cross-sectional and time-series dimension.

Unlike dynamic panel data estimators such as Hsaio, Pesaran and Tahmiscioglu (2002) which are based on maximum likelihood principles it is not necessary for the errors to be identically distributed. This is useful because of the wide variation of per-capita coffee consumption in our panels. Moreover, errors can be assumed to be non-independent in the sense that they are affected by common factors or shocks; the estimator will be consistent and asymtotically normal as long as either the number of common factors or the time series dimension tends to infinity.

Finally, and perhaps most importantly for this application, it is not necessary to make any assumptions about the evolution of the exogenous regressors. Thus, in this paper, the possibility that price and/or GDP may evolve according to a unit root proceess, do not pose any problems. In fact, the interpretation of the estimates is more intuitive if we consider that shocks to price or GDP are permanent, as is the case if a unit root is present.

We turn now to the theory underpinning this estimator. The approach of Han and Phillips (2007) is shown most clearly for a model without exogenous regressors, in which case the approach estimates

$$y_{it} = (1-\rho)\cdot\alpha_i + \rho \cdot y_{it-1} + \varepsilon_{it} . \tag{1}$$

The model can then be transformed to

$$2\Delta y_{it} + \Delta y_{it-1} = \rho \cdot \Delta y_{it-1} + \eta_{it}, \quad \eta_{it} = 2\varepsilon_{it} + (1+\rho)\cdot \Delta y_{it-1} . \tag{2}$$

With this transformation, Δy_{it-1} and η_{it} are uncorrelated when ε_{it} are white noise. A proof is provided in Han and Phillips (2007). Thus OLS estimation of Equation (2) is consistent when $n \cdot T \to \infty$,[5] providing the estimator

$$\hat{\rho} = \frac{\sum_{i=1}^{N}\sum_{t=3}^{T} \Delta y_{it-1}(2\Delta y_{it} + \Delta y_{it-1})}{\sum_{i=1}^{N}\sum_{t=3}^{T} (\Delta y_{it-1})^2} . \tag{3}$$

[5] In their paper, Han and Phillips (2007), consider estimating Equation (2) by GMM, but consider that the efficiency gain is too small to justify the increased complexity.

The key assumption in Han and Phillips (2007) is that $\varepsilon_{it} \approx iid\left(0,\sigma^2\right)$ with finite fourth moments, though the paper discusses the effect of relaxing these assumptions. If $E\left({\varepsilon_{it}}^2\right)$ varies across i, the estimator remains consistent and is asymptotically normal. Thus, the variance of the estimator $V_{OLS,T}$ should be expressed more generally as

$$\lim_{n\to\infty} V_{OLS,T} = \frac{\sum_{i=1}^{N} E\left(\sum_{t=3}^{T} \Delta y_{it-1}\eta_{it}\right)^2}{\sum_{i=1}^{N}\sum_{t=3}^{T}\left(\Delta y_{it-1}\right)^2}. \tag{4}$$

Cross sectional dependence is also considered. For this, Han and Phillips (2007) specify the errors as $\varepsilon_{it} = \sum_{k=1}^{K} \lambda_{ik} f_{kt} + v_{it}$, where f_{kt} are common shocks which are *i.i.d.* over t and independent of other shocks, λ_{ik} is the weight on each factor, and v_{it} are *i.i.d.*. In this case consistency requires either $T \to \infty$ or $K \to \infty$.

The residuals from the estimation can be averaged over the N individuals to provide an estimate of the variance of the errors and thus the standard error of $\hat{\rho}$. This holds when the variance is not constant across individuals. But, as indicated in Han and Phillips (2007) such estimates may slightly underestimate the true variance when N is small.

The specification with k exogenous variables estimated is

$$y_{it} = \alpha_i + \beta' x_{it} + u_{it}, \quad u_{it} = \rho \cdot u_{it-1} + \varepsilon_{it}, \tag{5}$$

where β' is a $l \times k$ matrix and $x_{it} = \left[x_{1it} \cdots x_{kit}\right]$ (the vector of exogenous variables). This model can be transformed to

$$y_{it} = (1-\rho)\cdot\alpha_i + \beta'\left(x_{it} - \rho\cdot x_{it-1}\right) + \rho\cdot y_{it-1} + \varepsilon_{it}. \tag{6}$$

It is useful at this stage to introduce some further notation: $z_{it} = (1-\rho)\cdot\alpha_i + \rho\cdot z_{it-1} + \varepsilon_{it}$. Then Equation (6) can be expressed as

$$z_{it} = (1-\rho)\cdot\alpha_i + \rho\cdot z_{it-1} + \varepsilon_{it}. \tag{7}$$

Han and Phillips (2007) apply the linear transformation described for the case without exogenous regressors to provide one set of moment conditions

$$E\sum_{t=3}^{T} \Delta z_{it-1}\left[\left(2\Delta z_{it} + \Delta z_{it-1}\right) - \rho\cdot\Delta z_{it-1}\right] = 0. \tag{8}$$

A second set of moment conditions arise after applying a within-transformation to Equation (7) providing the equation

$$y_{2it} - \rho \cdot y_{1it-1} = \beta'\left(x_{2it} - \rho \cdot x_{1it-1}\right) + \varepsilon_{2it}\,, \tag{9}$$

where $a_{2it} = a_{it} - \frac{1}{(T-1)}\sum_{t=2}^{T} a_{is}, \quad a_{1it-1} = a_{it-1} - \frac{1}{(T-1)}\sum_{s=1}^{(T-1)} a_{is}$ for $a \in \{x, y, \varepsilon\}$.

When α_i is allowed to be correlated with x_{it}, the within-group estimator is consistent and efficient, leading to the second set of moment conditions

$$E\sum_{t=2}^{T}\left(x_{2it} - \rho \cdot x_{1it-1}\right)\left[\left(y_{2it} - \rho \cdot y_{1it-1}\right) - \beta'\left(x_{2it} - \rho \cdot x_{1it}\right)\right] = 0\,. \tag{10}$$

To apply this estimator we begin by expressing Equations (8) and (10) as sample moment conditions. $\hat{\rho}$ is obtained using Equation (8). This estimate is then ‘plugged into’ Equation (10) to obtain $\hat{\beta}$ which is then ‘plugged into’ (8) to obtain a more accurate estimate of $\hat{\rho}$ and so on. This iterative process continues until the procedure converges.

Standard errors are computed using the conventional “$\left(D'\Omega^{-1}D\right)^{-1}$” method, where D is the expected score of Equations (8) and (10), and Ω is the variance of the moment conditions. Because both D and Ω are block-diagonal we can treat $\hat{\beta}$ as the true parameter when estimating the standard error of $\hat{\rho}$ and vice versa. More detail on this can be found in Han and Phillips (2007).

5. DATA, MODELS AND METHODOLOGY

The focus of this study is on the consumption of green coffee beans which are roasted or otherwise processed (typically in the country of consumption) to transform them into coffee for final consumption. We focus on green coffee beans for two reasons. First, this is the commodity which matters for developing countries. Second, a large panel data set is available on green coffee beans.

Our coffee consumption data is obtained from the ICO. Different data is available for importing members and non-member countries. For importing members we use the data on “disappearance” which provides a measure of consumption through subtracting re-exports from imports and adjusting the figures for changes in visible inventories. This data is available at quarterly intervals, but we choose to use annual data to avoid any seasonality which may exist at the quarterly level and because our income data is only available at annual intervals. For non-member countries we use imports minus exports because there is no data on changes in inventories from the ICO. We use population data available from the Penn World Tables (PWT) to transform coffee consumption to a per-capita series, which we denote as d_{it} for country *i* in year *t*.

We use the PWT real GDP per capita chain series as our income variable. In particular, we use the variable RGDPCH from PWT mark 6.1, measured in a common measure of value (international dollars). We denote the real per capita GDP of country *i* in year *t* as y_{it}.

We use the ICO composite indicator price for the price of green coffee beans. This is a weighted average of the price of arabica and mild beans and is the longest publicly available price series derived with a consistent methodology. It is the natural choice for our first investigation, which examines the era of export quotas, because the activation of quotas was triggered by this price variable. This series is available as monthly averages, which are averaged again to provide annual prices. As the series is in nominal US$ we adjusted it for changes in the US consumer price index (CPI) in order to have real prices.

Our primary model, Model 1, specifies a relationship between coffee demand, prices, and income that includes a quadratic term for income:

$$\ln d_{it} = \alpha_i + \beta_1 \ln y_{it} + \beta_2 \ln y_{it}{}^2 + \beta_p \ln p_t + u_{it}, \quad u_{it} = \rho \cdot u_{it-1} + \varepsilon_{it} \,. \tag{11}$$

This rearranges to

$$\begin{aligned} \ln d_{it} = {} & (1-\rho)\cdot\alpha_i + \beta_1 \cdot (\ln y_{it} - \rho \cdot \ln y_{it-1}) + \beta_2 \cdot \left(\ln y_{it}{}^2 - \rho \cdot \ln y_{it-1}{}^2\right) \\ & + \beta_p (\ln p_t - \ln p_{t-1}) + \rho \cdot \ln d_{it-1} + \varepsilon_{it}. \end{aligned} \tag{12}$$

The inclusion of this quadratic term was inspired by the fact that coffee demand appears to have plateaued in developed countries (Lewin *et al.* (2004)). If β_1 is positive and β_2 is negative the model incorporates a concave relationship between income and coffee demand. In other words, the income elasticity decreases as income increases.

In Model 2 a (log) linear relationship between income and coffee demand is postulated:

$$\ln d_{it} = \alpha_i + \beta_1 \ln y_{it} + \beta_p \ln p_t + u_{it}, \quad u_{it} = \rho \cdot u_{it-1} + \varepsilon_{it} \,. \tag{13}$$

This rearranges to

$$\ln d_{it} = (1-\rho)\cdot\alpha_i + \beta_1 \cdot (\ln y_{it} - \rho \cdot \ln y_{it-1}) + \beta_p (\ln p_t - \ln p_{t-1}) + \rho \cdot \ln d_{it-1} + \varepsilon_{it} \,. \tag{14}$$

The dynamic specification is used in both models is theoretically appropriate for coffee consumption, because coffee consumption is affected by habit. Thus the magnitude of ρ captures the degree of persistence of shocks due to their effect on coffee drinking habits. A key difference between our research and previous work is that we focus on demand for green coffee beans not the final demand for coffee. Moreover, we extend previous research on coffee demand through estimating a model (model 1) which allows for a concave relationship between income and coffee demand. In our models β_1, β_2 and β_p measure the contemporaneous effect of income and the price of coffee beans. Consequently, ρ measures the persistence of shocks other than changes in coffee price and income. There is no long run coefficient because price and income are separated from the dynamics of coffee consumption; thus after the dynamic effect of other shocks are 'partialled out', β_p is the price elasticities and taken together β_1 and β_2 represent the income elasticity. This is particularly appropriate if the price and income series contain a unit root with shocks having permanent effects.

To produce coffee suitable for final consumption green coffee beans must be roasted. The commonly applied transformation ratio is that 1.19 kilograms of green-coffee beans are required to produce 1 kilogram of roasted coffee beans suitable for final consumption. Almost all coffee consumed in a country is sourced from green coffee beans imported into that country.[6] Thus green coffee consumption is very closely related to final coffee consumption and hence, our estimates of ρ and the response to income accurately reflect the behaviour of final coffee consumption.

It is now worthwhile to consider how our price elasticities of demand for green coffee beans relate to the price elasticity of final coffee demand. In our specifications the price elasticity of demand for green coffee beans is constant. In interpreting this model it is useful to assume that the price elasticity of final demand is also constant.[7] In this case, even if downstream firms have market power, the mark-up does not change if the price of green coffee beans changes. Differences in the mark-up and costs of inputs other than beans (such as marketing and packaging) between countries are captured by the individual effect. Thus, our elasticities can be interpreted as the elasticity of final demand as long as mark-ups and costs remain unchanged over time.

The Han and Phillips (2007) estimator requires the regressors to be exogenous; meaning that they must not be correlated with the errors in any period. If our regressors are not exogenous then our estimates will be inconsistent. The exogeneity assumption is likely to be satisfied in our data. Coffee consumption does not affect income. The level of coffee demand in one country can be considered not to affect the world price of green

[6] Over the period 1996-2001, 94.5% of all coffee was exported as green coffee beans (Lewin *et al.* (2004)). A key explanation for this is that green coffee beans can be stored for considerable lengths of time but roast coffee is highly perishable.

[7] This was derived from consumer theory in Feuerstein (2002).

coffee beans, if we make the conventional assumption that each country is a ‘price-taker’ in a world market. It should be emphasised that if the retail price of coffee in each country had been used, then the variables may not be exogenous, as retail supply is unlikely to be perfectly price elastic.

We do not include the price of substitutes such as tea because studies of European countries have found that tea prices do not exert a statistically significant effect on coffee demand (e.g., Durevall (2006), Feuerstein (2002), Bettendorf and Verboven (2000)).

It has been argued that the demographic structure of a population can affect coffee consumption and some recent time series work has explicitly included demographic variables (e.g., Durevall (2006)). We do not include demographic variables (beyond expressing all our series in per capita terms) for two main reasons. First, our ultimate goal is to consider coffee consumption for a panel as broad as possible and there is very limited demographic data publicly available. Second, our panels consist of a relatively short time period (approximately 10 years); in this period there is little demographic change so any differences in the demographic structure of countries are effectively captured by the individual effect.

For panels consisting of non-ICO member countries it is necessary to use data on net imports rather than actual disappearance (consumption). Net imports are defined as imports *minus* re-exports. Previous research such as Durevall (2006), Feuerstein (2002) and Bettendorf and Verboven (2000) used net-import data when consumption data was not available.

We consider four panels. First, we investigate *Coffee Consumption in Importing Member Countries 1979-1988.* This panel incorporates ICO importing member countries during an interval in which ICA quotas were operating. Our estimates of price elasticities shed light on the effect of export quotas. Moreover, the relatively large amount of variation in the income levels of member countries in this panel allows us to meaningfully test our hypothesis that there is a concave relationship between income and coffee consumption; in other words we postulate that consumption becomes less responsive to increases in income as income increases. The panel includes 20 countries: Belgium/Luxemburg (the ICO data combines these two countries, with the PWT data weighted by population); Austria; Denmark; Finland; France; Germany; Greece; Hungary; Ireland; Italy; Japan; Netherlands; Norway; Poland; Portugal; Spain; Sweden; Switzerland; United States of America; United Kingdom. We commence our panel in 1979 so as to allow Poland to be included and to exclude the dramatic price increase of 1977.[8] 1988 was the final full year of operation of ICA quotas. We do not consider non-Member countries during this interval because the ICO price did not directly affect their consumption in this interval. There was no restriction on export quantities or prices

[8] Complete PWT data was not available before 1979. Durevall (2006) also commences after the 1977 price shocks.

to non-member countries so these countries were able to import coffee at prices substantially below the price paid by ICO members. A consequence of the quota system was that exporting members often had surplus coffee beans which they were unable to export officially at the prevailing price. Consequently, the ICO price does not affect the opportunity cost of domestic coffee consumption for producing members.

Second, we consider *Coffee Consumption in Importing Member Countries 1990-2000*. This panel considers the same group of importing member countries after the end of ICA quotas, in order to compare the situation before and after the implementation of a quota. Our panel ends in 2000 because this is the last year for which PWT data is available.

Third, we investigate *Net Coffee Imports in Non-Member Countries 1990-2000*. By using net-import data we are able to consider the broader panel of countries which are not members of the ICO. Our panel includes: Argentina; Australia; Barbados; Belize; Canada; Chile; Egypt; Iceland; Israel; Jordan; Republic of Korea; Lebanon; Lesotho; Mali; Mauritius; Morocco; Nepal; New Zealand; Romania; Saint Kitts and Nevis; Saint Lucia; Saint Vincent and the Grenadines; Senegal; Seychelles; Republic of South Africa; Tunisia; Turkey; Uruguay. We begin with the countries for which both ICO (import and re-export) data and PWT data were available between 1990 and 2000. Additionally, to improve the integrity of our data we require that two criteria are satisfied. First, we exclude any country which was a net exporter in any period. Second, we exclude any country whose per capita consumption changed by more than 100% between two years. The purpose of the second criterion is to eliminate any potentially erroneous series. We are cognisant that this criterion could affect the autoregressive coefficient, which was why we require such a large change before eliminating the country. This leaves us with 28 countries.

Fourth, we investigate *Net Coffee Imports 1990-2000*. In this investigation we examine net imports for both importing ICO members and non-members. The countries included in this panel are: Belgium/Luxemburg; Austria; Denmark; Finland; France; Germany; Greece; Hungary; Ireland; Italy; Japan; Netherlands; Norway; Poland; Portugal; Spain; Sweden; Switzerland; United States of America; United Kingdom; Czech Republic; Argentina; Australia; Barbados; Belize; Canada; Chile; Egypt; Iceland; Israel; Jordan; Republic of Korea; Lebanon; Lesotho; Mali; Mauritius; Morocco; Nepal; New Zealand; Romania; Saint Kitts and Nevis; Saint Lucia; Saint Vincent and the Grenadines; Senegal; Seychelles; Republic of South Africa; Tunisia; Turkey; Uruguay. For both sets of countries we use net-import data.[9] In total we have 49 countries and 10 years of observations which provide the largest sample size in this paper.

Key statistical features of the variables in our four panel data sets are presented in Table 1.

[9] It has been argued in section 5 that this does not materially affect the results for member countries and we only have net import data for non-members.

Table 1. Key Statistical Features of the Panels

Variable	Panel	Minimum	Maximum	Mean	Standard Deviation
Consumption (grams per person per year)	Importing Member Countries 1979-1988	473	14,588	5,756	3,645
	Importing Member Countries 1990-2000	377	13,383	5,897	3,071
Net Imports (grams per person per year)	Non-Member Countries 1990-2000	3	9,870	1,491	1,942
	Net-Imports 1990-2000	3	13,482	3,316	3,258
Income (GDP per capita -1996 US$)	Importing Member Countries 1979-1988	5,617	25,608	15,487	4,370
	Importing Member Countries 1990-2000	6,182	33,293	19,479	5,442
	Non-Member Countries 1990-2000	755	26,904	8,922	6,418
	Net-Imports 1990-2000	755	33,293	13,313	7,885
Price (ICO composite - 1996 US$ in national currency)	Importing Member Countries 1979-1988	87	894	214	114
	Importing Member Countries 1990-2000	20	211	60	34
	Non-Member Countries 1990-2000	29	506	139	84
	Net-Imports 1990-2000	20	506	107	78

6. EMPIRICAL RESULTS

Tables 2 and 3 set out the results of applying the Han and Phillips (2007) estimator to the panels described in the previous section. Turning first to Importing Member Countries, a 1% increase in the composite price of green coffee is expected to lead to a 0.15% decrease in coffee consumption in importing member countries between1978 and 1990. We would expect price to be inelastic, as a purpose of quotas is to raise prices in order to increase revenue. But if demand were elastic, a decrease in price would increase revenue. Our estimated price elasticity is slightly lower than historical estimates. For example, Herrmann (1986) estimated a price elasticity of -0.27, Akiyama and Duncan (1982) and Bettendorf and Verboven (2000) obtained estimates of around -0.2, and Feuerstein obtained an estimate of -0.18.

Table 2. Estimation Results of Model 1

Panel	$\hat{\rho}$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_p$
Importing Member Countries 1979-1988	0.2159*** (0.0769)	27.0109*** (4.8095)	-1.3787*** (0.2505)	-0.1499*** (0.0575)
Importing Member Countries 1990-2000	0.5878*** (0.0844)	23.5632*** (6.7111)	-1.1945*** (0.3446)	0.0142 (0.0424)
Non-Member Countries 1990-2000	0.8494*** (0.2185)	0.5388 (5.5704)	0.0449 (0.3215)	-0.2145*** (0.0663)
Net-Imports	0.7828*** (0.1768)	3.6595 (3.6044)	-0.1512 (0.1985)	-0.1161*** (0.0424)

Notes: *, **, *** denote statistical significance at the 10%, 5% and 1% level respectively.

Table 3. Estimation Results of Model 2

Panel	$\hat{\rho}$	$\hat{\beta}_1$	$\hat{\beta}_p$
Importing Member Countries 1990-2000 (inc Czech Republic)	0.5788*** (0.0653)	0.3415 (0.2723)	0.0304 (0.0415)
Non-Member Countries 1990-2000	0.8471*** (0.2188)	1.3092*** (0.5380)	-0.2149*** (0.0661)
Net Imports 1990-2000	0.7928*** (0.1760)	0.9483*** (0.3563)	-0.1145 (0.0424)

Notes: *, **, *** denote statistical significance at the 10%, 5% and 1% level respectively.

There is strong evidence that there is a concave relationship between income and coffee consumption for member countries in both intervals ; $\hat{\beta}_1$ is statistically significant and greater than zero, whereas $\hat{\beta}_2$ is statistically significant and less than zero. Thus, as income increases the effect of the quadratic component increases reducing income elasticity until the point where income elasticity is zero, which can be interpreted as a saturation point.

The point of zero income elasticity for importing members over the interval 1978-1989 is estimated to be US$18,000.[10] As income rises above this level our model implies that coffee consumption falls. The mean income in this panel is US$15,487.[11]

[10] This is calculated according to the formula $z = \exp^{\frac{\hat{\beta}_1}{-2\hat{\beta}_2}}$.

[11] This mean is calculated as $\sum_{n,T} \frac{y_{it}}{n \cdot T}$.

There are some countries in our panels with income levels in excess of this level and it is probably better to interpret the point of zero income elasticity as an asymptote. However, this does not detract from the overwhelming evidence of concavity, which explains the frequent references to "mature markets" in reports on coffee demand.

It is now worthwhile to consider how our results change when we consider the interval after the cessation of quotas. There is evidence that ρ is higher during the latter interval. Thus the degree of persistence of shocks is likely to have increased. A credible explanation for this is that the degree of persistence of shocks was distorted by quotas. This reinforces our decision to use panels on either side of 1989.

Perhaps the most striking feature of these results is that price is no longer statistically significant. This suggests that for developed countries price no longer matters for total coffee consumption (although there may be price elasticity with respect to individual retail products). Similarly, we believe income is no longer significant for these developed countries. The point of zero income elasticity (approximately 19,200) is very similar to the mean income of $19479 in this panel. Thus the use of a quadratic model is misleading, because although the income elasticity coefficients are statistically significant, the implied income elasticity is near zero for all countries in this panel. Table 3 estimates (log) linear specifications. From this table we can see that neither the income nor the price coefficients are statistically significant.

In the panel of non-Member countries 1990-2000, the autoregressive coefficient ($\hat{\rho}$) and the price coefficient ($\hat{\beta}_p$) are statistically significant but the two income coefficients ($\hat{\beta}_1$ and $\hat{\beta}_2$) are not. This can be attributed to the high degree of multi-collinearity between the variables which is greater when y_{it} is low. Another possible explanation for the inability to fit a concave relationship is that there could be a relatively slow increase in coffee consumption as incomes rise from low levels because coffee may be considered a nonessential 'luxury' good.

Consequently it is useful to refer to the results of estimating the (log) linear specification in Table 3. From this table we can see that all coefficients are statistically significant with the correct signs. An increase in real GDP per capita of 1% is expected to lead to a 1.3% increase in per capita coffee imports/consumption. Coffee is a normal good for non-member countries. A 1% increase in the composite price of green coffee is expected to lead to a 0.21% decrease in coffee consumption. Demand is relatively price inelastic.

We turn now to our combined panel labeled "Net Imports" in Tables 2 and 3. First, we note that the standard errors have shrunk with the increased sample size. Despite this, our estimates of β_1 and β_2 are not statistically significant for Model 1 in Table 2. Thus these results do not support the hypothesis that there is a concave relationship between incomes and coffee consumption around the world, despite the income inelasticity for the, typically developed, ICO members. Thus, it is worthwhile to note the (log) linear specifications set out in Table 3. We see very little change in $\hat{\rho}$. Our estimates of β_1 and β_2 lie between the estimates for the member and non-Member panels. Because of the apparent differences in ρ between these panels, we suggest that readers draw inferences from these separate investigations rather than from the combined panel.

7. CONCLUSIONS

Through the use of dynamic panel data models we have been able to improve understanding of certain aspects of coffee markets. First, we have robustly verified that further increases in the incomes of developed (ICO member) countries are not expected to lead to further increases in coffee consumption. This provides econometric support for the “saturated market” epithet. However, we have not found support for the hypothesis that there is a concave relationship between income and coffee demand in a panel including both developed member countries, and developing non-member countries. Consequently, in non-developed countries we should not necessarily expect to see income elasticity decrease as incomes increase. Second, we have obtained high quality estimates of the price elasticity of demand for coffee beans in non-member countries (approximately -0.21) which can be of use to policy makers concerned with the development of coffee producing countries. The low price elasticity also explains why prices have to fall to accommodate increased supply. Of further interest is the comparison between our results for the panel of ICO member countries over the interval 1979-1988, and the price elasticity results from previous research.

Key implications of our results for development policy are: First, measures which increase the price of coffee beans can be expected to have little effect on coffee sales; second, coffee consumption is unlikely to increase as incomes continue to increase in developed countries. However, an increase in incomes of other countries can be expected to increase demand for coffee beans. The use of the Han and Phillips (2007) estimator can thus provide new insights into markets which have a long history of empirical analysis with other methods.

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