

RESEARCH ARTICLE

Lessons from long-run (1975–2017) structural change in Colombia's coffee production

Mariana Saenz^{1*} , Diego Alvarez² and Gregory Brock¹

¹Department of Economics, Parker College of Business, Georgia Southern University, Statesboro, GA, USA and ²Universidad Nacional del Nordeste, Resistencia, Chaco, Argentina

*Corresponding author. Email: msayala@georgiasouthern.edu

(Received 23 December 2019; revised 31 December 2020; accepted 31 December 2020)

Abstract

Although coffee is still an important agricultural commodity in Colombia, the coffee share of GDP has significantly declined over the past 40 years. Controlling for changes in relative prices, factor endowments, and technological change, we analyze the coffee share decline in conjunction with other agricultural output by applying a Vector Error Correction model. The results indicate that while market liberalization policies contributed to the declining coffee share of GDP, the decline was partly offset by the end of coffee export quotas. Our results support policies in favor of assistance for farmers to compete in international markets.

Keywords: coffee share; Colombia; GDP function; structural change; VECM

Introduction

Coffee is an important economic sector for Colombia in terms of exports, agricultural land use, and job creation. Annual shipments of coffee were 6.6¹ percent of the country's total exports in 2017, and coffee plants covered 13.81² percent of the arable area of Colombia, which is the highest percentage of any single crop. Within Colombia, coffee directly employs 26 percent of all agricultural workers and provides income to more than 550,000 families living in 595 municipalities (Muñoz Ortega 2014). Moreover, coffee-growing regions enjoy a higher standard of living³ and relatively low levels of income inequality compared to noncoffee growing regions (Departamento Nacional de Planeación [DNP] 2013).

¹DANE (2019b) reported exports totaling 38,021,860 thousand of dollars, with coffee exports valued at 2,513,780 thousand of dollars.

²DANE (2019a) reported of 5,901,363 ha cultivated nationally for all crops, and 814,808 ha of coffee cultivated.

³Geographic regions where coffee is produced have a relatively high standard of living when measured by the Unsatisfied Basic Needs (UBN) index and the Multidimensional Poverty Index (MPI) (Garcia and Soto 2012; DNP 2013).

In the international coffee market, Colombia has been an important participant in terms of global production and exports. Between 2010 and 2017, Colombia produced an average of 7.6 percent of global physical coffee production and exported an average of 8.9 percent of world coffee exports by volume, surpassed only by Brazil and Vietnam (International Coffee Organization (ICO) 2020).⁴ During the same period, Colombia exported, on average, 86.3 percent of its coffee production, with the United States and the European Union buying 72 percent of Colombian coffee exports (ICO 2020; Federación Nacional de Cafeteros de Colombia (FNC) 2020c).

Despite the coffee sector's current importance for the Colombian economy, its share in the GDP has declined over the last few decades. In the late 1970s, coffee production accounted for roughly 1.64⁵ percent of Colombia's GDP, declining to 0.73 percent of the GDP in 2017 (Departamento Administrativo Nacional de Estadística (DANE) 2018). The decline in the coffee share of GDP mirrored a broader decline in Colombia's overall agriculture share of GDP. The agricultural share of GDP fell from 22 percent in the late 1970s to 7 percent in 2017 (DANE 2018), reflecting a classical development path of moving away from agriculture and rural lifestyle in general.

Specifically, for Colombia, the economy experienced structural changes that reflected variations in the importance of different sectors in the GDP. Between 1975 and 2017, the Colombian economy saw an allocation of resources away from the agricultural and manufacturing sector. These resources were principally moved toward the service sector (i.e., financial, insurance, real estate, and other services offered to businesses), followed by an increasing importance of the mining sector in the Colombian economy. Ocampo-Gaviria and Romero-Baquero (2015) discuss the structural changes in the GDP composition being attributed to the economic liberalization that included structural changes in exports and restructuring of the financial sector. Exports became more diversified and less dependent on coffee. The increased export diversification included a greater participation of the mining sector, thanks to its growth and favorable international prices. The restructuring of the financial sector included elimination of restrictions on foreign capital, elimination of forced credit and investment policies for different economic sectors, and privatization of government-owned financial institutions. Ocampo-Gaviria and Romero-Baquero (2015) indicate that in addition to economic liberalization, changes in the sectoral participation in the GDP were also attributed to the greater private participation in sectors traditionally reserved to the government, changes in the standard of living, and income distribution.⁶

Several scholarly articles have focused on the decline of the agricultural share of GDP in the course of economic growth (Anderson 1987; Martin and Warr 1993, 1994; Sun, Fulginiti, and Peterson 2007; Esposti 2012, 2014). Three major long-run driving forces have been identified as contributing to agriculture's decline compared with nonagricultural sectors, including (a) changes in relative prices of agricultural goods, (b)

⁴Brazil represented 35.7 percent of global coffee production and exported 28.7 percent of world coffee exports between 2010 and 2017. During the same period, Vietnam produced 16.9 percent of global coffee production and exported 18.8 percent of world coffee exports (ICO 2020).

⁵The average value of coffee share of GDP in the 1975–1979 period.

⁶For the manufacturing sector, more specific factors have been attributed to its declining contribution to GDP. Clavijo, Vera, and Fandiño (2012) explain that in the late 1980s, the manufacturing sector saw a decline in its share of GDP associated with insufficient provision of basic services such as telecommunications and roads, the boom of the mining–energy sectors accompanied by the relative scarcity of labor, and the persistent real appreciation of the Colombian peso.

differences in the technical change rates between sectors, and (c) changes in factor endowments intensification across sectors.

There is no available literature addressing the reasons for the decline in the coffee sector in terms of the simultaneous effect of relative coffee prices, differential sectoral technical change, and changes in relative intensity in factor endowments of capital and labor. However, we can infer that the decline in the coffee share of GDP is associated with changes in coffee prices and the labor endowment. It has been well documented that coffee profits are sensitive to international coffee prices (Giraud-Héraud, Le Mouel, and Réquillart 1995; World Bank 2003). Declining coffee prices relative to other traded goods reduce coffee's share in the GDP due to valuation effects and resources shifting away from coffee toward sectors with greater returns (Martin and Warr 1994). Low income elasticities of demand for agricultural goods relative to other traded goods (Martin and Warr 1994; Muhammad et al. 2011; Esposti 2012) can potentially be attributed to the decline in the relative coffee prices. Furthermore, high-income countries are the largest world coffee consumers (Grigg 2002)⁷ and have income elasticities of demand for agricultural goods 31 percent lower than low- and middle-income countries (Muhammad et al. 2011).

Similarly, a reduction in factor endowments can potentially be attributed to the decline in coffee output. With labor fleeing rural conflict zones in Colombia, the wages of the remaining workers rise, leading to higher costs for coffee producers (World Bank 2003). Labor costs account for 70–80 percent of coffee production costs with no offsetting improvement in labor productivity (World Bank 2003). Further, the shortage of rural labor leaves the coffee crop overly exposed to pests and not being harvested at the right time (Ocampo-Lopez and Alvarez-Herrera 2017). As many farms in Colombia are located on steep slopes in the Andes Mountains, substituting capital for labor is problematic (Forero-Álvarez and Furio 2010), resulting in lower yields per hectare compared with Brazilian and Vietnamese coffee farms. For example, the average coffee yield in the 2010–2017 period was 0.85 tons per hectare in Colombia, compared with 1.4 tons per hectare in Brazil and 2.35 tons per hectare in Vietnam (Food and Agriculture Organization of the United Nations (FAO) 2020).

We examine the declining coffee's share of GDP in Colombia by assessing the changes in relative prices, factor endowments, technological change, and three policy shocks affecting Colombia's economy. Those policy shocks are the collapse of the International Coffee Agreement (ICA) quota system in July 1989, the constitutional and legal reforms undertaken within Colombia between 1990 and 1994, and the 2016 peace agreement between the Revolutionary Armed Forces of Colombia (FARC)⁸ and the Colombian government.

The ICA was an international commodity agreement between coffee-producing countries and consuming countries. First signed in 1962, the ICA maintained exporting countries' quotas and kept coffee prices high and stable. Empirical studies by Akiyama and Varangis (1990) and Herrmann (1986, 1988) suggest that the ICA was successful at raising the prices of coffee traded within the ICA. When ICA export quotas were suspended, producing countries lost most of their influence in the international market to increase coffee prices. The end of the quotas caused a sharp decline in international coffee prices as major exporters started to sell coffee aggressively (Giraud-Héraud, Le Mouel, and Réquillart 1995). The five-year average ICO composite price indicator fell

⁷Developed countries account for 71.5 percent of world coffee consumption.

⁸Abbreviation in Spanish for "Fuerzas Armadas Revolucionarias de Colombia."

from \$1.34 per pound in the quota years (1984–1988) to an average of \$0.77 per pound in the nonquota period (1990–1994) (Daviron and Ponte 2005). Comparing the coffee share of GDP before and after the ICA, our data indicate that during the ICA quota period for the sample years (1975–1989), coffee production accounted for roughly 1.45 percent of Colombia's GDP. After the collapse of the export quotas, the coffee's share fell to an average of 0.97 percent in the 1990–2017 period (DANE 2018).

The second policy shock was the constitutional and legal reforms undertaken from 1990 to 1994, which pursued a clear opening and internationalization of Colombia's economy. The reforms included a Constituent Assembly that created the 1991 National Constitution, and structural/institutional reforms in labor and foreign exchange markets that impacted the finance and commercial sectors. The reforms drastically altered the public/private sector mix in the Colombian economy (Montenegro 1995). Jaramillo (2001) compares the determinants of changes in farmers' returns for different tradable crops before and after the market liberalization in the early 1990s. For a tradable commodity, such as coffee, farmers' returns fell primarily due to the negative impact of international coffee prices and the real exchange appreciation of the Colombian peso (Jaramillo 2001). In contrast, farmers' returns on nontradable crops increased (Jaramillo 2001). While a more detailed review of the literature that analyzes the ICA⁹ and the reforms in the early 1990s is beyond the scope of this article, we explore these policy shocks having distinctive influences on the behavior of coffee's share of GDP.

Additionally, we empirically assess the effect of the 2016 peace agreement between the FARC and the government on the coffee share of GDP. The presence of the FARC has affected the agricultural sector by diluting the rural labor supply through the forced displacement of rural workers, changing farmers' on-farm work decisions, and recruiting rural workers. Forced displacement of rural workers is the result of violent attacks on the population, forced recruitment of minors, and economic road blocks such as illegal seizure of livestock and crops, and expropriation of land (Defensoría del Pueblo 2001; Fernandez, Ibáñez, and Peña 2011; Sánchez-Cuervo and Aide 2013). Research of rural labor markets in Colombia has also shown that changes in the rural labor supply have been used as means of coping with violent shocks (Fernandez, Ibáñez, and Peña 2011). Fernandez, Ibáñez, and Peña (2011) found that households in the rural areas of Colombia reduce their time spent on on-farm work and increase their supply of labor on nonagricultural activities in response to violent shocks. Another factor affecting the rural labor supply is the FARC's recruitment of rural workers for their guerrillas as an alternative of employment during economic downturns (Dube and Vargas 2013) or through coercion and intimidation (Saab and Taylor 2009; Dube and Vargas 2013). In addition to diluting the rural labor supply, the FARC has also appropriated public funds (Richani 1997), stripping the agricultural sector of potential funds for rural development.

In terms of the coffee sector, the coffee-producing regions are strategically important to the FARC. Coffee production is geographically located in a corridor that links the center of the country to the pacific coast and the northeast part of the country (Defensoría del Pueblo 2001). The presence of the FARC in the coffee production area has not only diluted the rural labor supply, but it has also contributed to crop

⁹For a more extensive discussion on the ICA, see Herrmann (1986, 1988), Akiyama and Varangis (1990), Bohman and Jarvis (1990), Bates (1997), Akiyama et al. (2001), Daviron and Ponte (2005), and Mehta and Chavas (2008).

substitution. The FARC has contributed to the dilution of the coffee labor supply, as the migrant workforce required by the cyclical coffee economy has provided a pool of potential workers for illegal crops (Rettberg 2010; Dube and Vargas 2013). Additionally, illegal crop production related to drug trafficking by the FARC has penetrated the formal economy, leading to the substitution of legal crops. Coca crops supported by the FARC are a profitable alternative to economic uncertainty in coffee production (Defensoría del Pueblo 2001). Greater profitability in coca production has resulted in coffee farmers selling their lands. Other coffee farmers have converted their lands to the cultivation of coca leaves (Rettberg 2010). Consequently, the rural areas that saw coca production rise have become more violent (Angrist and Kugler 2008), changing coffee growers' productive decisions. The risk of violence has been found to negatively impact the Colombian coffee grower's decision to continue coffee production and on the percentage of the farm allocated to coffee (Ibañez-Londoño, Muñoz-Mora, and Verwimp 2013).

This article fills a gap in the literature by analyzing the dynamic coffee sector behavior in conjunction with other agricultural output, while accounting for the effects that the ICA collapse, market liberalization policies, and the peace agreement process had on the evolution of the coffee share of GDP. Specifically, we analyze the effects of relative prices, factor endowments, technological change, the collapse of the ICA quota system, the liberalization of markets, and the peace agreement process on the change in the coffee share of GDP in Colombia. We estimate those effects using a Vector Error Correction model (VECM) that looks at both the short- and long-run dynamics. The long-run equilibrium results are used to estimate price, output, and Stolper–Samuelson elasticities.

The article is organized as follows: The next section discusses the economic theory to analyze the coffee and other agricultural output shares of GDP. The section that follows outlines the econometric model. The last two sections present the results and conclude with policy implications.

Economic theory

We assume that the Colombian economy is a three-sector, three-fixed-factor, small open economy with competitive equilibria in all input and output markets making all prices exogenous and independent of domestic demand (Esposti 2014).¹⁰ The assumption of a small open economy is appropriate, given the participation of Colombia in world coffee production. Colombia's share of world coffee production fell from 12 percent in 1970 to 6.25 percent in 2011 (Cano et al. 2012).

Following Kohli (1978, 1990), Fox and Kohli (1998), and Sun, Fulginiti, and Peterson (2007), we assume that the economy's aggregate technology is convex, exhibits constant returns to scale, has free disposability, and has nonincreasing marginal rates of substitution and transformation. Under profit maximization, the competitive equilibrium can be characterized as the solution to the problem of maximizing revenues subject to technology, endowment of domestic resources, and a vector of positive output prices at each

¹⁰As noted by Krivonos (2004), for the period following the collapse of the ICA in 1989, this is not an unreasonable assumption. Even during the ICA regulatory system, the difficulties associated with negotiating and insuring compliance with the agreements suggested that producing countries were not able to collude perfectly, making the agreement ineffective. Karp and Perloff (1993) test the price-taking hypothesis in the case of Brazil and Colombia—the two largest exporters for the 1961–1962 crop year to the 1983–1984 crop year—and found their estimated behavior to be competitive.

point in time. Thus, the aggregate technology at time t can be represented by a Gross Domestic Product (GDP)¹¹ function—or revenue function—defined as follows:

$$\pi(\mathbf{p}_t, \mathbf{x}_t, t) = \max_{\mathbf{y}_t} \{ \mathbf{p}'_t \mathbf{y}_t : (\mathbf{y}_t, \mathbf{x}_t) \in T_t \} \mathbf{p}, \mathbf{y} \in R^3, \mathbf{x} \in R^3, \tag{1}$$

where \mathbf{y}_t is a vector of final outputs (i.e., coffee (C), other agricultural output¹² (A), and nonagricultural output (E)), \mathbf{p}_t is a vector of final output prices (i.e., P_C , P_A , and P_E), \mathbf{x}_t is a vector of factor endowments (i.e., capital (K), labor (L), and land (R)), t is a proxy for technical change, and T_t is the production possibilities set.¹³

The solution to the revenue maximization problem given in equation 1 is a function of the exogenous output prices and the revenue maximizing output that depends on the factor endowments and technology (Esposti 2014). For the empirical functional form of the revenue maximizing solution, $\pi(\mathbf{p}, \mathbf{x}, t)$, the Translog functional form was chosen. The Translog revenue functional form yields simple estimating equations for the coffee share of GDP and the share of GDP devoted to factor endowments. Differentiating the Translog revenue function with respect to the log of the price of outputs and invoking Hotelling (1932)’s lemma yield to the output shares of GDP as dependent variables (Kohli 1978). Similarly, the factor endowment shares of GDP are found by differentiating the Translog revenue function with respect to the log of factor endowments (Feenstra 2016). The Translog functional form is also less restrictive than other popular functional forms such as the Cobb Douglas and the CES (Villezca-Becerra and Shumway 1992; Sadoulet and De Janvry 1995).

The Translog functional form for the GDP function, after omitting the time subscript for simplicity, is defined as

$$\begin{aligned} \ln \pi(\mathbf{p}_t, \mathbf{x}_t, t)_{ij} = & \alpha_0 + \sum_i \alpha_i \ln p_i + \sum_j \beta_j \ln x_j + \frac{1}{2} \sum_i \sum_h \gamma_{ih} \ln p_i \ln p_h \\ & + \frac{1}{2} \sum_j \sum_k \varphi_{jk} \ln x_j \ln x_k + \sum_i \sum_j \delta_{ij} \ln p_i \ln x_j + \sum_i \gamma_{it} \ln p_i t \\ & + \sum_j \varphi_{jt} \ln x_j t + \gamma_t t + \frac{1}{2} \gamma_{tt} t^2, \end{aligned} \tag{2}$$

where $i, h \in \{C, A, E\}$ and $j, k \in \{L, K, R\}$. A system of output and input shares of GDP is derived from the Translog GDP function in equation 2 to analyze the effects of relative prices, factor endowments, and technological change on the coffee share of GDP. The output shares of GDP (S_i) are derived by applying Hotelling (1932)’s lemma and imposing symmetry conditions to the Translog GDP function (Sun,

¹¹The GDP function is also called “revenue function” when referring to the aggregate economy (Esposti 2014).

¹²Other agricultural output includes forestry, hunting, fishing, livestock production, and cultivation of crops (excluding coffee).

¹³Under the assumptions made on T , the revenue function is nondecreasing in output prices and quantities of fixed inputs and is linearly homogeneous and convex with respect to output prices (Esposti 2012).

Fulginiti, and Peterson 2007; Esposti 2012). Thus, the i th output share of GDP is defined as follows:

$$S_i = \frac{\partial \ln \pi}{\partial \ln p_i} = \alpha_i + \sum_h \gamma_{ih} \ln p_h + \sum_j \delta_{ij} \ln x_j + \gamma_{it}t, \tag{3}$$

for $i = C, A, E$ and where the symmetry conditions are $\gamma_{ih} = \gamma_{hi}$. Likewise, we can also find the inverse demand equations for the factor endowments in share form (V_j) after imposing the symmetry conditions (Kohli 1978; Mckay, Lawrence, and Vlastuin 1983; Feenstra 2016). The share of GDP devoted to factor j is defined as follows:

$$V_j = \frac{\partial \ln \pi}{\partial \ln x_j} = \beta_j + \sum_k \varphi_{jk} \ln x_k + \sum_i \delta_{ij} \ln p_i + \varphi_{jt}t. \tag{4}$$

For $j = L, K, R$ and where the symmetry conditions are $\varphi_{jk} = \varphi_{kj}$. After imposing linear homogeneity in output prices and fixed inputs, the system of output and input shares of the GDP to estimate¹⁴ is

$$S_C = \alpha_C + \gamma_{CC} \ln \left(\frac{p_C}{p_E} \right) + \gamma_{CA} \ln \left(\frac{p_A}{p_E} \right) + \delta_{CL} \ln \left(\frac{L}{R} \right) + \delta_{CK} \ln \left(\frac{K}{R} \right) + \gamma_{Ct}t, \tag{5}$$

$$S_A = \alpha_A + \gamma_{CA} \ln \left(\frac{p_C}{p_E} \right) + \gamma_{AA} \ln \left(\frac{p_A}{p_E} \right) + \delta_{AL} \ln \left(\frac{L}{R} \right) + \delta_{AK} \ln \left(\frac{K}{R} \right) + \gamma_{At}t, \tag{6}$$

$$V_K = \beta_K + \delta_{CK} \ln \left(\frac{p_C}{p_E} \right) + \delta_{AK} \ln \left(\frac{p_A}{p_E} \right) + \varphi_{KL} \ln \left(\frac{L}{R} \right) + \varphi_{KK} \ln \left(\frac{K}{R} \right) + \varphi_{Kt}t, \tag{7}$$

$$V_L = \beta_L + \delta_{CL} \ln \left(\frac{p_C}{p_E} \right) + \delta_{AL} \ln \left(\frac{p_A}{p_E} \right) + \varphi_{LL} \ln \left(\frac{L}{R} \right) + \varphi_{KL} \ln \left(\frac{K}{R} \right) + \varphi_{Lt}t, \tag{8}$$

where S_E and V_R can be estimated from equations 5 through 8 since output shares and input shares sum to one.

Econometric model

We estimate the system of equations 5–8 as a dynamic multiequational model where all variables are simultaneously determined and, therefore, endogenous. Vector autoregressive (VAR) models are used to study the dynamic interdependence between stationary time series. VAR models have been used to assess the impacts of agricultural prices, labor, land, and technological changes on the agricultural share of GDP (Esposti

¹⁴Note that by symmetry $\delta_{ij} = \delta_{ji}$. The following restrictions are imposed on the shares: (1) linearly homogeneity in output prices (i.e., $\sum_i \alpha_i = 1$, $\sum_i \gamma_{ih} = 0$, $\sum_i \delta_{ij} = 0$, and $\sum_i \gamma_{it} = 0$); and (2) linearly homogeneity in fixed inputs (i.e., $\sum_j \beta_j = 1$, $\sum_j \varphi_{jk} = 0$, $\sum_j \delta_{ij} = 0$, and $\sum_j \varphi_{jt} = 0$).

2012, 2014) and the effect of agricultural production on economic growth (Tiffin and Irz 2006). Other applications of VAR models in the agriculture sector include the assessment of energy price shocks (Wang and McPhail 2014), public research and development strategies (Esposti 2002), and the interdependence between agricultural commodity prices, land use, and food markets (Piroli, Ciaian, and Kancs 2012; Pierre and Kaminski 2019).

However, spurious regression results can be obtained when regressing a nonstationary time series on one or more nonstationary series in the VAR model (Gujarati 2015). A viable solution to deal with nonstationary time series is to estimate the VAR model in first differences if the time series are first-difference stationary. However, the VAR model in first differences is misspecified if the nonstationary time series obey a stationary equilibrium relationship (Statacorp LLC 2017), because the VAR model would only estimate short-run dynamics among the time series. Accordingly, the VAR model can be extended to a VECM¹⁵ if the nonstationary time series follow a stationary equilibrium relationship or cointegration (Becketti 2013; Gujarati 2015). In the VECM framework, the regression of a nonstationary series on another nonstationary series does not result in a spurious regression (Gujarati 2015). Similar to the VAR model, the VECM fits the first differences of the nonstationary series, but a lagged vector of error-correction terms is added to represent the cointegration or long-term equilibrium relationships between the time series (Becketti 2013). The vector of error-correction terms represents short-term deviations from the long-term equilibrium relationships (Becketti 2013).¹⁶

Assuming that long-term relationships (i.e., cointegration) between the variables exist, the dynamic simultaneous equation model can be specified as a VECM. Specifically, the VECM with lag order k is defined as follows:

$$\Delta \mathbf{y}_t = \boldsymbol{\alpha}(\boldsymbol{\beta}'\mathbf{y}_{t-1} + \boldsymbol{\mu} + \boldsymbol{\rho}t) + \sum_{i=1}^{k-1} \boldsymbol{\Gamma}_i \Delta \mathbf{y}_{t-i} + \boldsymbol{\gamma} + \boldsymbol{\varepsilon}_t, \quad (9)$$

where \mathbf{y} is the $p \times 1$ vector of variables, $\boldsymbol{\varepsilon}$ is a $p \times 1$ vector of independent and identically normally distributed disturbances, and Δ denotes first differences. The vector \mathbf{y}

¹⁵In the agricultural sector, the VECM has been used to estimate input and output shares as a function of prices, factor endowments, and technological change (Reziti and Ozanne 1999). Additionally, VECM analyses have been used to estimate the supply of agricultural commodities (Weliwita and Govindasamy 1997; Tambi 1999), private investment in agriculture (Kuiper and Thijssen 1996), price interdependencies between agricultural and energy markets (Busse, Brümmer, and Ihle 2012), and price transmission in agricultural products (Esposti and Listorti 2013; Haile *et al.* 2017).

¹⁶The VECM is called Error Correction Model (ECM) if a unique cointegrating relationship exists. The ECM has been used to explain the decline in the agriculture share of GDP in terms of factor endowments, prices, technological change, and agricultural policies (Martin and Warr 1993; McKay, Morrissey, and Vaillant 1999; Sun, Fulginiti, and Peterson 2007). Other applications of ECM analyses in the agricultural sector include the estimation of machinery demand (Vasavada and Cook 1996), fertilizer demand (Mergos and Stoforos 1997), price volatility and interdependencies (Rezitis and Stavropoulos 2011; Algeri 2014; Abdelradi and Serra 2015; Serra 2015; Würriehausen, Ihle, and Lakner 2015), crop supply (Abdulai and Rieder 1995), and crops' area response to output prices (Clark and Klein 1996). Additionally, the ECM framework has been used to investigate agricultural commodity price linkages between developed and developing countries (Yavapolkul, Gopinath, and Gulati 2006) and to reexamine causality relationships such as the farmland price–rent relationship (Shigeto, Hubbard, and Dawson 2008) and the agricultural sector–economic growth causality direction (Awokuse and Xie 2015).

corresponds to the variables in the system of equations 5–8 which include S_C , S_A , V_K , V_L , $\log(P_C/P_E)$, $\log(P_A/P_E)$, $\log(L/R)$, and $\log(K/R)$. The long-term equilibria is defined by $\beta'y_{t-1} + \mu + \rho t$, where β is a $p \times r$ matrix of cointegrating relationships, μ and ρ are $r \times 1$ vectors of parameters, t is a time trend, and r is the number of cointegrating vectors. The short-run dynamics are defined by the $p \times r$ error correction matrix (i.e., α), the $p \times p$ coefficient matrix of short-run dynamic relationships between the elements of y (i.e., Γ_i), and a $p \times 1$ vector of parameters γ . The error correction parameters, α , are interpreted as the adjustment speed in y to deviations from the long-run equilibria. The VECM, as defined in equation 9, restricts the cointegrating equations to be trend stationary (Statacorp LLC 2017).

In order to account for the structural break in equation 9, we introduce an intervention dummy following the discussion in Joyeux (2007)¹⁷. The VECM in equation 9 with a structural break is redefined as

$$\Delta y_t = \alpha(\beta'y_{t-1} + \mu + \rho t) + \theta D_{t-k} + \sum_{i=1}^{k-1} \Gamma_i \Delta y_{t-i} + \gamma + \sum_{i=0}^{k-1} \kappa_i I_{t-i} \tag{10}$$

$$+ \delta_1 \text{Policy}_{90} + \delta_2 \text{Peace treaty} + \delta_3 \text{Recession} + \varepsilon_t,$$

where D_{t-k} is the structural change or collapse of the quota system in 1989 and I_t in the VECM framework accounts for the first difference in the structural change variable (Joyeux 2007). The structural change or intervention dummy, D_{t-k} , takes the value of one for $1990 \leq t \leq 2017$ and zero otherwise, and I_t is a dummy variable taking the value of one for $t = 1990$ and zero otherwise. We also include three additional variables to account for major events: (1) a Policy_{90} variable accounting for the market liberalization changes in the early 1990s (equals one for the years 1990–1994 and zero otherwise),¹⁸ (2) a Peace Treaty variable controlling for the effects of peace negotiations between the government and the FARC (equals one for the years 2012–2016 and zero otherwise), and (3) a Recession variable controlling for the Great Recession (equals one for the years 2008–2009 and zero otherwise).

Results

This study uses annual time-series data from 1975 to 2017 for the Colombian economy. Variable definitions, units of measurement, sources, and descriptive statistics are presented in Table 1. The annual average share of coffee and other agricultural output in the GDP is 1.1 percent and 11.4 percent, respectively. Descriptive data indicate a declining trend in the coffee share, other agricultural output share, and relative coffee and other agricultural output prices.

The empirical estimation of equation 10 consists of investigating the nonstationary nature of the variables and their first differences, testing for the number of cointegrating

¹⁷See the Joyeux (2007) discussion on the introduction of dummies in the VECM. Following the Joyeux (2007) discussion, we assume that some or all of the time series follow a trending pattern, and the cointegrating equations are stationary before and after the structural break.

¹⁸Agricultural output (excluding coffee) is not further divided to include tradable vs. nontradable crops, because the focus of analysis is the decline of the contribution of coffee production in relation to other agricultural output and nonagricultural output. Furthermore, the analysis of the VECM is limited by data availability. Given the data constraint, adding additional parameters reduces the statistical power of hypothesis testing (Statistics Online Support (SOS) 2015).

Table 1. Definition, descriptive statistics, and data source^a

Variable	Definition	Mean	Std. Dev.
S_C	Share of coffee (parchment) output in the GDP at current national prices (i.e., coffee output/GDP)	0.011	0.003
S_A	Share of agricultural output (excluding coffee) in the GDP at current national prices (i.e., agricultural output (excluding coffee)/GDP)	0.114	0.047
V_K	Share of capital stock in the GDP at current national prices (i.e., capital stock/GDP)	6.306	0.876
V_L	Share of labor compensation (i.e., labor income of employees and self-employed) in the GDP at current national prices (i.e., labor compensation/GDP)	0.478	0.013
p_C	Coffee (parchment) price index (base year 2011; index equals 100 in 2011)	29.766	28.513
p_A^b	Weighted average of price indices for agricultural output, excluding coffee (index)	41.759	38.15
p_E^c	Weighted average of price indices for nonagricultural output (index)	40.187	39.364
L	Number of persons engaged (employed and self-employed) adjusted by human capital (millions)	17.015	5.888
K	Capital stock (millions of 2011 U.S. Dollars)	1,187,187	445,350
R	Agricultural land (km ²)	443,119	13,362

Data source: authors' calculation for S_C , S_A , p_C , p_A , and p_E using data from the National Administrative Department of Statistics (DANE) and the National Planning Department (DNP) (DNP 2014; DANE 2018). V_K was estimated using the value for capital stock, K , obtained from the Penn World Table 9.0 (Feenstra, Inklaar, and Timmer 2015) and the GDP data obtained from the DANE (DANE 2018). V_L and L were obtained from the Penn World Table 9.0 (Feenstra, Inklaar, and Timmer 2015). R was obtained from the World Development Indicators (World Bank 2019).

^a S_C and S_A were estimated by dividing the value of coffee output and agricultural output (excluding coffee) by the GDP, respectively. For example, for the period of analysis, on average, the coffee output value represented 1.14 percent of the GDP. Coffee production between 1975 and 1990 represented, on average, 1.45 percent of the GDP, while between 2000 and 2017 it represented, on average, 0.83 percent of the GDP.

^bThe price index for agricultural output (excluding coffee) was estimated as the weighted average of price indices with base year 2011 for: (1) other crop production, (2) animal production, and (3) forestry, fishing, and hunting. The weights were estimated by dividing each activity's output value (i.e., other crop production, animal production, and forestry/fishing/hunting) by the agricultural output.

^cThe price index for nonagricultural output was estimated as the weighted average of price indices with base year 2011, for the main classifications of nonagricultural economic activity. The weights were estimated by dividing each activity's output value by the GDP.

relationships, and identifying the lag order of the VECM. In this article, we examine the nonstationary relationship of the variables by investigating the existence of unit roots in the level of the variables as well as in their first differences using the modified Augmented Dickey–Fuller Test proposed by Elliott et al. (1996) (DF-GLS)¹⁹ and the Innovational Outlier model unit root test proposed by Clemente et al. (1998) (CMR-IO) tests. Both the DF-GLS and CMR-IO tests complement each other when

¹⁹The DF-GLS test has greater power than the standard Augmented Dickey–Fuller test for unit root in terms of small-sample size and power (Elliott, Rothenberg, and Stock 1996).

investigating the nonstationarity of the variables. While both test for the unit root in the series, the CMR-IO test takes into account the presence of a structural break in the time series (Perron and Vogelsang 1992; Clemente, Montañés, and Reyes 1998). If the structural break is ignored, the unit root test can lose power (Perron 1989). As noted by Zivot and Andrews (1992), the CMR-IO test helps identify a potential structural breakpoint time period as the test chooses the structural breakpoint that gives the least favorable result for the unit root null hypothesis.

Table 2 reports the unit root results for the levels and first differences in the data. The DF-GLS test indicates that the levels of all variables, except the relative price of coffee, are nonstationary. However, when allowing for a structural break, the CMR-IO test indicates that the levels of all variables, except the coffee share, other agricultural output share, and their relative prices are nonstationary. The CMR-IO test indicates that the coffee share, other agricultural output share, and their relative prices are stationary with a mean break in the early 1990s and in 2006. We conclude from the unit root tests on the level of the data that the time series for coffee share, other agricultural output share, and their relative prices are stationary with a structural break, while all other variables are nonstationary. The CMR-IO test suggests a break in the data in the early 1990s, which matches our expectation of a structural break due to the collapse of the ICA quota system and the market liberalization reforms. Furthermore, the CMR-IO test indicates a break in the data later in the 2000s, which we partly capture with a Great Recession dummy variable. Table 2 also indicates that the first differences of all variables are stationary, permitting us to use the first differences of the variables as the dependent variables in the VECM.

After investigating the nonstationary nature of the data, we test for the number of cointegrating equations which, in the VECM, determines the number of long-term relationships among the variables. Table 3 presents the results from Johansen's maximum likelihood cointegration test on equation 10 using the maximum eigenvalue statistic.²⁰ The null hypothesis of no cointegration is found to be rejected at the 5 percent significance level, indicating the existence of long-run or equilibrium relationships among the variables. The maximum eigenvalue statistic identifies two distinct cointegrating vectors.

Lastly, we proceed to identify the lag order for the estimation of the VECM. Four different information criteria were used to investigate the lag order for the VECM (i.e., Likelihood Ratio (LR) test, Akaike (AIC), Schwarz's Bayesian (SBIC), and Hannan and Quin (HQIC)). The HQIC and the SBIC suggest a lag order of one, while the LR and the AIC suggest a lag order of two. Since the VECM estimates the first difference of the data, we use a lag order of two to estimate the VECM.

Long-run dynamics

Normalization restrictions are imposed to identify the two long-run cointegrating relationships suggested by Johansen's cointegration test. Given our interest in the output share equations to evaluate structural changes and elasticities, we impose the normalization restrictions to identify the share of coffee and other agricultural output.

²⁰Johansen's maximum likelihood cointegration test is conducted before including additional dummy variables that account for the policy changes in the early 1990s, the Great Recession, and the peace treaty negotiations. As a result, the VECM follows the Joyeux (2007) discussion on the inclusion of a structural break variable (i.e., collapse of the ICA quota system) in the VECM.

Table 2. Unit root tests

Variable	Levels ^a				First Difference ^a			
	DF-GLS ^b		CMR-IO ^c		DF-GLS ^d		CMR-IO ^c	
	Lags	t-stat	t-stat	Break	Lags	t-stat	t-stat	Break
S_C	2	-2.71	-4.829**	1990***	2	-1.8*	-8.224***	1996
S_A	2	-1.91	-4.002*	2006**	4	-2.04**	-7.546***	2005
V_K	1	-1.75	-2.598	2002**	1	-3.55***	-5.114***	1989
V_L	1	-1.82	-2.546	2001	2	-2.82***	-7.793***	2013*
$\ln\left(\frac{P_C}{P_E}\right)$	1	-3.53**	-4.253*	1990**	4	-1.7*	-6.53***	1985
$\ln\left(\frac{P_A}{P_E}\right)$	1	-1.89	-4.478**	1991*	3	-1.71*	-5.584***	1995
$\ln\left(\frac{L}{R}\right)$	1	-1.86	-2.73	1985**	1	-3.76***	-5.683***	2010*
$\ln\left(\frac{K}{R}\right)$	2	-1.16	-3.445	2005***	3	-2.1**	-5.101***	1994

***, **, * indicate significant effects at the 1 percent, 5 percent, and 10 percent levels, respectively.

^aNg and Perron (1995) proposed a backward lag selection to minimize bias on the test. They proposed to select the lag such that the last lagged difference is significant (i.e., absolute value of the t-statistic for the last lag is greater than 1.6). Once the last lagged difference was found significant, the Modified Akaike Information Criterion (MAIC) was considered to select the number of lags to conduct the unit root test as proposed by Ng and Perron (2001). Ng and Perron (2001) show that the MAIC criterion is useful when using the DF-GLS test because of good power. The lag chosen for the CMR-IO test was the same lag reported by the MAIC criterion in the DF-GLS test.

^bDF-GLS unit root test for the data in levels: Ho: unit root vs. Ha: trend stationary. DF-GLS test critical values (Elliott, Rothenberg, and Stock 1996): -3.77 (1 percent level), -3.19 (5 percent level), and -2.89 (10 percent level).

^cThe CMR-IO model with one structural break was used to test for the unit root (Perron and Vogelsang 1992) where Ho: unit root with single structural break vs. Ha: stationary series with a single structural break. The CMR- IO model critical values are: -4.97 (1 percent level), -4.27 (5 percent level), and -3.86 (10 percent level).

^dDF-GLS unit root test for the differenced data: Ho: unit root vs. Ha: level stationary. DF-GLS test critical values (Elliott, Rothenberg, and Stock 1996): -2.633 (1 percent level), -1.95 (5 percent level), and -1.607 (10 percent level).

Table 3. Johansen's maximum likelihood cointegration rank test in the presence of structural breaks^a

Hypothesis $H_0: \text{rank} \leq r$	Max-Eigenvalue Statistic $H_a: \text{rank} \leq r + 1$	
	Test Statistic	5% Critical Value
r		
0	74.93**	55.5
1	52.56**	49.42
2	42.92	43.97
3	35.71	37.52
4	22.32	31.46
5	21.08	25.54
6	13.08	18.96
7	5.37	12.25

** indicates significance at the 5 percent level. The number of cointegrating vectors is r .

^aAn intercept in the VAR model and a trend in the cointegrating equation were assumed. The Johansen's maximum likelihood cointegration rank test was conducted, assuming that the structural break was on 1989 and before the additional major events were included (i.e., Policy₉₀, Peace Treaty, and Recession variables). Excluding the additional major event variables allows us to follow the discussion on Joyeux (2007) on testing for the number of cointegrating vectors in the presence of one structural break.

Furthermore, we assume that the discrepancy from the long-run equilibrium relationship in coffee and other agricultural output shares is corrected by the adjustment in those output shares. That is, within the cointegrating system, all variables, except S_C and S_A , are weakly exogenous.²¹ After imposing the normalization and weakly exogenous conditions, the VECM of lag order two with two cointegrating relationships has stationary cointegrating relationships and the errors are normally distributed.²²

Tables 4 and 5 present the maximum likelihood estimates of the restricted long-run relationships and elasticity values obtained from the long-run estimates. The results in Table 4 indicate that own-relative prices and technological change are expected to significantly increase coffee and other agricultural output shares in the long run. Other results in Table 4 indicate capital intensity per agricultural land to be negatively associated with the Sector A share (i.e., agricultural output excluding coffee) in the long run.

Table 5 presents the estimation of different elasticities to assess the structural changes in the long run. Our result of the long-run elasticity of coffee supply is consistent with the long-run elasticity estimate of Akiyama and Varangis (1990) for Colombia.²³ Before the major changes in the structure of the economy took place (i.e., 1975–1994), the results show negative, but small (in absolute value) own-price

²¹A variable is weakly exogenous if it does not respond to a disequilibrium in the long-run relationship, in which case the speed of adjustment is zero (Enders 2015).

²²The Jarque–Bera test fails to reject the null hypothesis that the disturbances are normally distributed at the 1 percent significance level. The Lagrange multiplier test fails to reject the null hypothesis that there is no autocorrelation in the residuals at the standard significance levels. The cointegration equations before (i.e., 1975–1989) and after (i.e., 1991–2017) the break are all level stationary at the 10 percent significant level.

²³Akiyama and Varangis (1990) reported the 10-year elasticity of coffee supply for Colombia to be 0.74, while our estimate for the period 1975–2017 is 0.77.

Table 4. Maximum likelihood estimates of the long-run coffee and noncoffee/agricultural share in the GDP^a

Cointegrating Vectors		
Variable	$\hat{\beta}_1$	$\hat{\beta}_2$
S_C	1	
S_A		1
$\ln\left(\frac{P_C}{P_E}\right)$	-0.01*** (0.001)	-0.001 (0.004)
$\ln\left(\frac{P_A}{P_E}\right)$	-0.001 (0.004)	-0.094*** (0.019)
$\ln\left(\frac{L}{R}\right)$	0.018 (0.013)	0.019 (0.043)
$\ln\left(\frac{K}{R}\right)$	0.007 (0.007)	0.197*** (0.024)
t	-0.001* (0.0003)	-0.005*** (0.001)

***, **, * indicates significant effects at the 1 percent, 5 percent, and 10 percent levels, respectively. Standard errors in parentheses.

^aNormalization restrictions for the identification of the two cointegrating equations are: (1) cointegrating vector 1 normalizes S_C (i.e., $\beta_{11} = 1$) and excludes S_A , V_K , and V_L ; (2) cointegrating vector 2 normalizes S_A (i.e., $\beta_{21} = 1$) and excludes S_C , V_K , and V_L . The two cointegrating vectors match the model specification in equations 5 and 6.

supply elasticities. The latter result seems counterintuitive, but should not be surprising, as during this period, the coffee market was highly regulated. Binswanger *et al.* (1987) point out that negative supply elasticities could be the result of intertemporal optimization. That is, if there is an expectation of an increase in price to last into the future, producers find it desirable to build up inventory which reduces the present supply of coffee. For this reason, it is more informative to assess the own-price elasticities after the major structural changes happened in the Colombian economy.

After the major structural changes (i.e., after the 1989–1994 period) to the Colombian economy, agricultural output, including coffee, became more responsive to changes in their own prices. Specifically, our estimation suggests that coffee output became price-elastic after the market liberalization policies were introduced. Our results are consistent with the effect of the elimination of a quota system on the prices of agricultural commodities. For example, in a study on the effect of the end of coffee export quotas on price transmission in France, Germany, and the United States, Lee and Gómez (2013) found that coffee retail prices became responsive to changes in international prices. In addition, our results indicate that the agricultural sector became even more responsive to its own prices during the period in which the peace negotiations between the government and the FARC took place.

The estimated cross-price elasticities of supply for coffee and Sector A (i.e., agricultural output excluding coffee) were all positive and inelastic, indicating that coffee and other agricultural output are complements in production. Coffee output supply increases when other agricultural output prices increase and vice versa. The latter result

Table 5. Translog GDP function elasticity estimates for selected years^a

Elasticities	1975–1994	1995–2011	2012–2017	1975–2017
Price elasticities of output supplies				
$\epsilon_{ih} = \frac{\partial \ln y_i}{\partial \ln p_h} = \left\{ S_i + \frac{\gamma_h}{S_i} - 1 \text{ for } i = h \in \{C, A\}; S_h + \frac{\gamma_h}{S_i} \text{ for } i \neq h \in \{C, A\} \right\}$				
ϵ_{CC}	-0.183	1.158	2.856	0.771
ϵ_{CA}	0.223	0.271	0.414	0.268
ϵ_{AA}	-0.157	0.85	2.532	0.616
ϵ_{AC}	0.021	0.024	0.04	0.025
Output elasticities : $\epsilon_{ij} = \frac{\partial \ln y_i}{\partial \ln x_j} = \frac{\delta_{ij}}{S_i} + V_j$				
ϵ_{CK}	5.947	4.874	2.418	4.986
ϵ_{CL}	-1.083	-3.521	-6.688	-2.914
ϵ_{AK}	5.043	2.699	-2.087	3.028
ϵ_{AL}	0.33	0.118	-0.231	0.16
Price elasticities of inverse factor demands (Stolper–Samuelson elasticities) $\epsilon_{ji} = \frac{\partial \ln w_j}{\partial \ln p_i} = \frac{\delta_{ij}}{V_i} + S_i$				
ϵ_{KC}	0.012	0.004	0.001	0.007
ϵ_{LC}	-0.026	-0.033	-0.036	-0.03
ϵ_{KA}	0.105	0.024	-0.01	0.055
ϵ_{LA}	0.096	0.015	-0.013	0.047

^aThe elasticity values were found at each time period and then averaged over the reference period. The estimation of elasticities follows the discussion on Feenstra (2016) and McKay, Lawrence, and Vlastuin (1983).

is consistent with the fact that coffee and other agricultural output international prices move together because of competition for land (de Gorter et al. 2013). An exogenous increase in the relative price of coffee is usually accompanied by an increase in the price of other agricultural output.

However, for specific crops, cross-price elasticities of supply can be positive or negative depending on the degree of competition for inputs (e.g., labor and land) used on the production of such crops. For example, Ferreira Filho and Horridge (2014) found that policies increasing the demand for ethanol in Brazil stimulate the demand for sugarcane, resulting in higher prices for sugarcane. The greater price of sugarcane then influences the production of other crops depending on whether the competition for land with sugarcane is more or less intense (Ferreira Filho and Horridge 2014). The results of Ferreira Filho and Horridge (2014) are consistent with negative and inelastic cross-price elasticities of output supply between sugarcane and coffee. Similarly, coffee is a close substitute for coca in terms of proper area conditions for growth (Muñoz-Mora, Tobón, and D’Anjou 2018).²⁴

The long-run output elasticities presented in Table 5 give indirect evidence of the factor intensities used in production by defining the intensity of production in factor *j* as positive output elasticities (Feenstra, Hanson, and Swenson 2000). Estimated output elasticities indicate that an increase in the endowment of capital favored all types of

²⁴There is no literature analyzing the influences among the coffee sector and the rest of the agricultural sector from the short- and long-run perspectives.

Table 6. The speed of adjustment coefficients

	$\hat{\alpha}_1$	$\hat{\alpha}_2$
ΔS_{C_t}	-0.49*** (0.09)	-0.02 (0.03)
ΔS_{A_t}	-1.97** (0.93)	-1.37*** (0.26)

***, **, * indicates significant effects at the 1 percent, 5 percent, and 10 percent levels, respectively. Standard errors in parentheses. $\hat{\alpha}_i$ is the error correction parameter for the i th cointegration vector.

agricultural production before 1994. After the market liberalization reforms in the early 1990s, increases in the endowment of capital favored coffee production more than that of other agricultural output, as changes in capital had a larger impact on coffee output.

Long-run output elasticities also indicate that increases in labor (i.e., employment adjusted by human capital) did not favor coffee production. During the peace negotiations between the FARC and the government, coffee production was the most responsive to changes in labor. Additionally, the production of agricultural output (excluding coffee) (i.e., Sector A) went from positively responding to changes in labor in the period prior to the negotiations to negatively responding to changes in labor during the peace talks. The negative output elasticities for labor seem counterintuitive as agricultural goods are thought to be labor-intensive. However, since labor was measured by employment adjusted by human capital, our results show evidence of an educated labor force moving away from agricultural production (Huffman 1980).

The Stolper–Samuelson elasticities are the counterparts to the output elasticities (Kohli 1990) and allow us to assess the distributional effects of changes in the prices, all else equal. An increase in the price of coffee favors capital and hurts labor, with changes in the price of coffee having a less-than-proportional impact on the price of capital and labor. For all other agricultural output, increases in their price favored both capital and labor, except during the peace negotiations period.

Short-run dynamics

Tables 6 and 7 show how the share of coffee and other agricultural output is influenced in the short run by deviations from the long-run equilibrium and the short-term dynamics. Table 6 identifies the speed of adjustment parameters or the speed at which the share of coffee and other agricultural output responds to long-run deviations. The results indicate that about 50 percent of the long-run disequilibrium in the previous period's coffee share is corrected in one year by changes in its share contribution to the GDP. The agricultural sector (excluding coffee) significantly responds to long-run disequilibrium in its own share and the coffee share. That is, the agricultural sector's (excluding coffee) share completely adjusts in 6 months to correct for the long-run disequilibrium in the previous period's coffee share. Similarly, the agricultural sector's (excluding coffee) share completely adjusts in approximately 9 months to correct for the long-run disequilibrium in its previous period's share.

Table 7 presents the results for the short-term estimated coefficients. For the coffee sector, coffee production responds positively to changes in the share of labor compensation in the GDP. All other agricultural output responds positively to changes in the economy's capital endowment. The impact of the collapse of the 1989 quota system

Table 7. Nonstructural maximum likelihood estimates of the dynamic short-run error correction model

Variable	ΔS_{C_t}	ΔS_{A_t}	ΔV_{K_t}	ΔV_{L_t}	$\Delta \ln\left(\frac{P_C}{P_E}\right)_t$	$\Delta \ln\left(\frac{P_A}{P_E}\right)_t$	$\Delta \ln\left(\frac{L}{R}\right)_t$	$\Delta \ln\left(\frac{A}{R}\right)_t$
$\Delta S_{C_{t-1}}$	-0.308 (0.258)	2.54* (1.469)	43.571 (46.720)	-0.838 (1.367)	-35.963 (24.609)	6.41 (7.835)	-5.913 (4.003)	-2.57 (2.896)
$\Delta S_{A_{t-1}}$	0.02 (0.042)	0.659** (0.278)	-7.186 (6.841)	0.023 (0.2)	0.027 (3.603)	0.597 (1.147)	0.118 (0.586)	0.353 (0.424)
$\Delta V_{K_{t-1}}$	0.00001 (0.001)	0.011* (0.006)	0.265 (0.209)	-0.002 (0.006)	0.073 (0.11)	0.075** (0.035)	0.02 (0.018)	0.004 (0.013)
$\Delta V_{L_{t-1}}$	0.051* (0.031)	-0.2 (0.168)	1.119 (5.638)	-0.282* (0.165)	3.941 (2.97)	0.158 (0.945)	0.264 (0.483)	0.087 (0.349)
$\Delta \ln\left(\frac{P_C}{P_E}\right)_{t-1}$	0.004 (0.003)	-0.015 (0.018)	-0.346 (0.517)	0.004 (0.015)	0.474* (0.272)	0.098 (0.087)	0.077* (0.044)	0.029 (0.032)
$\Delta \ln\left(\frac{P_A}{P_E}\right)_{t-1}$	-0.001 (0.006)	-0.054 (0.037)	0.577 (1.1)	-0.018 (0.032)	-0.304 (0.579)	-0.071 (0.184)	-0.093 (0.094)	-0.066 (0.068)

(Continued)

Table 7. (Continued.)

Variable	ΔS_{C_t}	ΔS_{A_t}	ΔV_{K_t}	ΔV_{L_t}	$\Delta \ln\left(\frac{\rho_C}{\rho_E}\right)_t$	$\Delta \ln\left(\frac{\rho_A}{\rho_E}\right)_t$	$\Delta \ln\left(\frac{L}{R}\right)_t$	$\Delta \ln\left(\frac{K}{R}\right)_t$
$\Delta \ln\left(\frac{L}{R}\right)_{t-1}$	-0.021 (0.014)	-0.155** (0.077)	-1.128 (2.58)	0.001 (0.075)	-1.864 (1.359)	0.277 (0.433)	0.222 (0.221)	0.119 (0.16)
$\Delta \ln\left(\frac{K}{R}\right)_{t-1}$	0.008 (0.024)	0.377*** (0.14)	-0.006 (4.216)	0.204* (0.123)	0.587 (2.221)	-0.056 (0.707)	-0.311 (0.361)	0.078 (0.261)
D_{t-k}	0.003*** (0.001)	0.042*** (0.008)	-0.121 (0.143)	-0.001 (0.004)	0.037 (0.076)	-0.002 (0.024)	-0.008 (0.012)	-0.014 (0.009)
Policy ₉₀	-0.002* (0.001)	-0.019*** (0.007)	-0.348 (0.219)	0.009 (0.006)	-0.036 (0.115)	-0.008 (0.037)	0.012 (0.019)	0.008 (0.014)
Peace Treaty	-0.001 (0.001)	-0.002 (0.005)	0.121 (0.169)	0.012** (0.005)	-0.123 (0.089)	0.067** (0.028)	-0.01 (0.015)	0.007 (0.01)
Recession	-0.002 (0.002)	0.01 (0.011)	0.082 (0.28)	-0.001 (0.008)	0.041 (0.148)	0.086* (0.047)	0.016 (0.024)	0.015 (0.017)
R ²	0.54	0.58	0.51	0.44	0.34	0.53	0.72	0.85

***, **, * indicates significant effects at the 1 percent, 5 percent, and 10 percent levels, respectively. Standard errors in parentheses.

and market reforms in the early 1990s had similar and stronger impacts in the agricultural sector (excluding coffee) relative to the coffee sector. The collapse of the quota system in 1989 had a small positive significant economic impact in both the coffee sector and the agricultural sector (excluding coffee). However, the market liberalization reforms in the early 1990s contributed to the overall decline in the agricultural sector. Our results indicate that it was the market liberalization reforms in the early 1990s and not the collapse of the quota system that acted as the policy shock contributing to the decline in the coffee share of GDP. Interestingly, other results indicate that the peace negotiations between the government and the FARC resulted in significant increases in the labor compensation share of GDP and the relative prices for the agricultural sector (excluding coffee). The 2008–2009 Great Recession significantly increased the relative prices of other agricultural output at the same time as the output share in the GDP continued to decline.

The other results from the short-dynamics estimates in Table 7 show that increases in relative coffee prices significantly increase the following period's labor intensity per land area. Increases in capital endowments are expected to significantly increase the agricultural sector (excluding coffee) relative prices and their output share in the GDP on the following period, while greater capital intensity per agricultural land area increases the labor share compensation on the following period.

Last, coffee output contribution to the GDP significantly increases all other agricultural output share in the GDP, which can be explained by the similarities in the trends in commodity prices due to competition for land and global macroeconomic trends (de Gorter, Drabik, and Just 2013; Barbaglia, Wilms, and Croux 2016). Our results intuitively support that global macroeconomic factors transmit faster to coffee production.

Conclusions

The importance of coffee for Colombia's economy goes well beyond coffee sales and employment. We used a Translog functional form for aggregate technology, and the results indicate that relative coffee prices and technological change significantly impact the share of coffee in the GDP in the long run. The short-run estimation results indicate that the decline in the coffee share cannot be attributed to the collapse of the coffee quota regime in 1989. Instead, the market liberalization and other regulatory reforms that took place in the early 1990s significantly reduced the size of the coffee sector in Colombia. The market liberalization and other regulatory reforms made coffee production more responsive to changes in the economy's employment and coffee prices. As market liberalization policies appeared to have a negative impact on coffee production, farmers continue to require assistance to compete in international markets.

A comparison of the returns for different tradable commodities before and after market liberalization policies, Jaramillo (2001) shows that the returns for coffee fell due to the appreciation of the exchange rate and the negative impact of international prices. Two different programs have been implemented to mitigate the negative impact of low international coffee prices on coffee farm income. The first program is called the "specialty coffee" extension program, which is currently offered through the National Federation of Coffee Growers of Colombia (FNC)²⁵ with resources from the national government to help farmers produce specialty coffees (Ministerio de Agricultura y

²⁵Abbreviation in Spanish for Federación Nacional de Cafeteros de Colombia (FNC).

Desarrollo Rural 2020). The specialty coffee support extension program provides technical support for coffees that have differentiated characteristics of origin, preparation, or sustainable production (FNC 2020b). This allows coffee producers to obtain a greater price for their crop. Technical support provides assistance to meet the requirements of different seals, codes of conduct, and certifications that accredit the coffee as a specialty coffee (FNC 2020b).

The second program—Governmental Incentive for Coffee Equity (IGEC)²⁶ 2019—lasted until December 2019 and provided income support to coffee producers. The IGEC 2019 program helped mitigate the negative impact that international markets had on farm income by providing a subsidy if the coffee's domestic reference price fell below an established price floor at the time of the physical sale (FNC 2019). The IGEC 2019 program protected coffee farmers from drops in the domestic reference price that is dependent on the price in the New York Stock Exchange, the quality premium recognized for Colombian coffee, and the exchange rate of the Colombian peso against the US dollar (FNC 2020a). Our results favor the continuation of income support programs such as the IGEC 2019 to counteract the negative impact of market liberalization policies on the coffee production share in the national GDP. Further, our results indicate that coffee and agricultural output (excluding coffee) are complements in production, with agricultural output (excluding coffee) responding to the coffee output's share contribution in the GDP. Coffee and other agricultural output are dependent on each other due to similarities in the way commodity prices trend, competition for scarce land, and global macroeconomic trends.

Other estimations in the short run indicate that coffee production responds positively to increases in the share of labor compensation in the GDP. In the framework of the peace accords signed in 2016 between the Colombian government and the FARC, specific rural labor reforms were included in the agreement with potential to improve the production of coffee. The peace accords support the strengthening of the rural labor market by facilitating access to employment rights, strengthening the labor inspection system, and providing provisions for an occupational risk subsidy (Office of the High Peace Commissioner 2017).

The importance of the coffee sector in the Colombian economy in terms of employment, standard of living for rural households, and lower levels of income inequality also highlights the importance of assessing the sector as a foundation for rural economic development. For example, illegal coca crop substitution policies need to be assessed in conjunction with coffee sector policies. Illicit drug prohibition policies directed to restrict the illicit drug supply have been found to generate political instability (Saenz and Barilla 2020). Alternatively, in Colombia, coffee and coca can be considered close substitutes in terms of conditions for growth (Muñoz-Mora, Tobón, and D'Anjou 2018), suggesting that increasing farmers' net return from producing coffee could reduce coca production. Therefore, an assessment of the spillover effects of policies supporting the production of coffee, such as farmers' support programs to improve their ability to compete in international markets, and a strengthening of rural labor markets are important to generate economic stability in rural communities affected by armed conflicts.

Funding statement. This research received no specific grant from any funding agency, commercial, or not-for-profit sectors.

²⁶Abbreviation in Spanish for Incentivo Gubernamental para la Equidad Cafetera (IGEC).

Conflict of Interest. None declared.

References

- Abdelradi, F., and T. Serra.** 2015. "Asymmetric Price Volatility Transmission Between Food and Energy Markets: The Case of Spain." *Agricultural Economics* 46(4): 503–513.
- Abdulai, A., and P. Rieder.** 1995. "The Impacts of Agricultural Price Policy on Cocoa Supply in Ghana: An Error Correction Estimation." *Journal of African Economies* 4(3): 315–335.
- Akiyama, T., J. Baffes, D. Larson, and P. Varangis.** 2001. "Commodity Market Reforms: Lessons of Two Decades." in *World Bank Regional and Sectoral Studies*. Washington, D.C.: The World Bank.
- Akiyama, T., and P.N. Varangis.** 1990. "The Impact of the International Coffee Agreement on Producing Countries." *The World Bank Economic Review* 4(2): 157–173.
- Algieri, B.** 2014. "A Roller Coaster Ride: An Empirical Investigation of the Main Drivers of the International Wheat Price." *Agricultural Economics* 45(4): 459–475.
- Anderson, K.** 1987. "On Why Agriculture Declines with Economic Growth." *Agricultural Economics* 1(3): 195–207.
- Angrist, J.D., and A.D. Kugler.** 2008. "Rural Windfall or a New Resource Curse? Coca, Income, and Civil Conflict in Colombia." *The Review of Economics and Statistics* 90(2): 191–215.
- Awokuse, T.O., and R. Xie.** 2015. "Does Agriculture Really Matter for Economic Growth in Developing Countries?" *Canadian Journal of Agricultural Economics* 63(1): 77–99.
- Barbaglia, L., I. Wilms, and C. Croux.** 2016. "Commodity Dynamics: A Sparse Multi-Class Approach." *Energy Economics* 60: 62–72, DOI: 10.1016/j.eneco.2016.09.013.
- Bates, R.H.** 1997. *Open-Economy Politics. The Political Economy of the World Coffee Trade*. Princeton, New Jersey: Princeton University Press.
- Beckett, S.** 2013. *Introduction to Time Series Using Stata*. College Station, Texas: StataCorp LLC.
- Binswanger, H., M.-C. Yang, A. Bowers, and Y. Mundlak.** 1987. "On the Determinants of Cross-Country Aggregate Agricultural Supply." *Journal of Econometrics* 36(1-2): 111–131.
- Bohman, M., and L.S. Jarvis.** 1990. "The International Coffee Agreement: Economics of the Nonmember Market." *European Review of Agricultural Economics* 17(1): 99–118.
- Busse, S., B. Brümmer, and R. Ihle.** 2012. "Price Formation in the German Biodiesel Supply Chain: A Markov-Switching Vector Error-Correction Modeling Approach." *Agricultural Economics* 43(5): 545–560.
- Cano, C.G., C. Vallejo, E. Caicedo, J.S. Amador, and E.Y. Tique.** 2012. "El Mercado Mundial Del Café y Su Impacto En Colombia." *Borradores de Economía* 710(1): 1–56.
- Clark, J.S., and K.K. Klein.** 1996. "Nerlovian Area Response as an Error Correction Model: An Application to Western Canadian Agriculture." *Empirical Economics* 21(4): 501–512.
- Clavijo, S., A. Vera, and A. Fandiño.** 2012. *La Desindustrialización En Colombia: Análisis Cuantitativo de Sus Determinantes*. Bogotá: Asociación Nacional de Instituciones Financieras (ANIF).
- Clemente, J., A. Montañés, and M. Reyes.** 1998. "Testing for a Unit Root in Variables with Double Change in the Mean." *Economics Letters* 59(2): 175–182.
- Daviron, B., and S. Ponte.** 2005. *The Coffee Paradox: Global Markets, Commodity Trade and the Elusive Promise of Development*. London, UK: Zed Books.
- Defensoría del Pueblo.** 2001. *Informe Defensorial Sobre el Desplazamiento Forzado por la Violencia en Colombia*. Bogota, Colombia: Defensoría del Pueblo.
- de Gorter, H.D., D. Drabik, and D.R. Just.** 2013. "Biofuel Policies and Food Grain Commodity Prices 2006–2012: All Boom and No Bust?" *AgBioForum* 16(1): 1–13.
- Departamento Administrativo Nacional de Estadística (DANE).** 2018. *Cuentas Nacionales*. Available at: <https://www.dane.gov.co>.
- Departamento Administrativo Nacional de Estadística (DANE).** 2019a. *Encuesta Nacional Agropecuaria (ENA)*. Available at: <https://www.dane.gov.co>.
- Departamento Administrativo Nacional de Estadística (DANE).** 2019b. *International Trade: Exports*. Available at: <https://www.dane.gov.co>.
- Departamento Nacional de Planeación (DNP).** 2013. "Una Estrategia para la Competitividad de la Caficultura Colombiana." Documento Consejo Nacional de Política Económica y Social (Conpes) 3763.
- Departamento Nacional de Planeación (DNP).** 2014. *Estadísticas Históricas de Colombia*. Available at: <https://www.dnp.gov.co>.

- Dube, O., and J.F. Vargas.** 2013. "Commodity Price Shocks and Civil Conflict: Evidence From Colombia." *Review of Economic Studies* 80(4): 1384–1421.
- Elliott, G., T.J. Rothenberg, and J.H. Stock.** 1996. "Efficient Tests for an Autoregressive Unit Root." *Econometrica* 64(4): 813–836, DOI: 10.2307/2171846.
- Enders, W.** 2015. *Applied Econometric Time Series*, 4th Edition. Hoboken, New Jersey: Wiley Series in Probability and Statistics.
- Esposti, R.** 2002. "Public Agricultural R&D Design and Technological Spill-Ins: A Dynamic Model." *Research Policy* 31(5): 693–717.
- Esposti, R.** 2012. "The Driving Forces of Agricultural Decline: A Panel-Data Approach to the Italian Regional Growth." *Canadian Journal of Agricultural Economics* 60(3): 377–405.
- Esposti, R.** 2014. "On Why and How Agriculture Declines: Evidence From the Italian Post-WWII Experience." *Structural Change and Economic Dynamics* 31(1): 73–88.
- Esposti, R., and G. Listorti.** 2013. "Agricultural Price Transmission Across Space and Commodities During Price Bubbles." *Agricultural Economics* 44(1): 125–139.
- Federación Nacional de Cafeteros de Colombia (FNC).** 2019. *Incentivo Gubernamental para la Equidad Cafetera – IGEC. Preguntas Frecuentes.* Available at: <https://federaciondefcafeteros.org>.
- Federación Nacional de Cafeteros de Colombia (FNC).** 2020a. *Learn to Sell your Coffee.* Available at: <https://federaciondefcafeteros.org>.
- Federación Nacional de Cafeteros de Colombia (FNC).** 2020b. *Specialty Coffee.* Available at: <https://federaciondefcafeteros.org>.
- Federación Nacional de Cafeteros de Colombia (FNC).** 2020c. *Estadísticas Cafeteras.* Available at: <https://federaciondefcafeteros.org/wp/estadisticas-cafeteras/> (accessed December 2020).
- Feenstra, R.C.** 2016. *Advanced International Trade: Theory and Evidence*, 2nd Edition. Princeton, New Jersey: Princeton University Press.
- Feenstra, R.C., G.H. Hanson, and D.L. Swenson.** 2000. "Offshore Assembly From the United States: Production Characteristics of the 9802 Program." In: *The Impact of International Trade on Wages* (pp. 85–125). Chicago, Illinois: University of Chicago Press.
- Feenstra, R.C., R. Inklaar, and M.P. Timmer.** 2015. "The Next Generation of the Penn World Table." *American Economic Review* 105(10): 3150–3182.
- Fernandez, M., A.M. Ibáñez, and X. Peña.** 2011. "Adjusting the Labor Supply to Mitigate Violent Shocks: Evidence from Rural Colombia." 39. Serie Documentos Cede-Elca.
- Ferreira Filho, J.B.D.S., and M. Horridge.** 2014. "Ethanol Expansion and Indirect Land Use Change in Brazil." *Land Use Policy* 36(1): 595–604.
- Food and Agriculture Organization of the United Nations (FAO).** 2020. *FAOSTAT.* Available at: <http://www.fao.org/faostat>.
- Forero-Álvarez, J., and V.J. Furio.** 2010. "Colombian Family Farmers' Adaptations to New Conditions in the World Coffee Market." *Latin American Perspectives* 37(2): 93–110.
- Fox, K.J., and U. Kohli.** 1998. "GDP Growth, Terms-of-Trade Effects, and Total Factor Productivity." *Journal of International Trade & Economic Development* 7(1): 87–110.
- García, C.A., and Y. Soto.** 2012. "El Impacto de la Caficultura en las Condiciones de Vida de los Productores de Colombia." *RegionEs* 7(1): 5–24.
- Giraud-Héraud, E., C. Le Mouel, and V. Réquillart.** 1995. "Competition and Collusion on the World Coffee Market." *European Review of Agricultural Economics* 22(3): 336–353.
- Grigg, D.** 2002. "The Worlds of Tea and Coffee: Patterns of Consumption." *GeoJournal* 57(4): 259–270.
- Gujarati, D.** 2015. *Econometrics by Example*, 2nd Edition. London, UK: Palgrave.
- Haile, M.G., M. Kalkuhl, B. Algeri, and S. Gebreselassie.** 2017. "Price Shock Transmission: Evidence From the Wheat-Bread Market Value Chain in Ethiopia." *Agricultural Economics* 48(6): 769–780.
- Herrmann, R.** 1986. "Free Riders and Redistributive Effects of International Commodity Agreements: The Case of Coffee." *Journal of Policy Modeling* 8(4): 597–621.
- Herrmann, R.** 1988. "National Interests in International Commodity Agreements: A Theoretical Framework and Quantitative Results for the Export Quota Scheme in Coffee." *Agriculture and Governments in an Interdependent World. Proceedings of the Twentieth International Conference of Agricultural Economics*, Buenos Aires, Argentina, pp. 697–710.
- Hotelling, H.** 1932. "Edgeworth's Taxation Paradox and The Nature of Demand and Supply Functions." *Journal of Political Economy* 40(5): 577–616.

- Huffman, W.E.** 1980. "Farm and Off-Farm Work Decisions: The Role of Human Capital." *The Review of Economics and Statistics* 62(1): 14–23.
- Ibañez-Londoño, A.M., J.C. Muñoz-Mora, and P. Verwimp.** 2013. *Abandoning Coffee under the Threat of Violence and the Presence of Illicit Crops. Evidence from Colombia*. 35. Serie Documentos Cede. Documentos Cede. Available at: <http://economia.uniandes.edu.co>.
- International Coffee Organization (ICO).** 2020. *Historical Data on the Global Coffee Trade*. Available at: http://www.ico.org/new_historical.asp.
- Jaramillo, C.F.** 2001. "Liberalization, Crisis, and Change: Colombian Agriculture in the 1990s." *Economic Development and Cultural Change* 49(4): 821–846.
- Joyeux, R.** 2007. "How to Deal with Structural Breaks in Practical Cointegration Analysis?." in Rao B. Bhaskara (ed.), *Cointegration for the Applied Economist*, 2nd Edition (pp. 195–221). Basingstoke, UK: Palgrave Macmillan.
- Karp, L.S., and J.M. Perloff.** 1993. "A Dynamic Model of Oligopoly in the Coffee Export Market." *American Journal of Agricultural Economics* 75(2): 448–457.
- Kohli, U.** 1978. "A Gross National Product Function and the Derived Demand for Imports and Supply of Exports." *The Canadian Journal of Economics* 11(2): 167–182.
- Kohli, U.** 1990. "Price and Quantity Elasticities in U.S. Foreign Trade." *Economic Letters* 33(3): 277–281.
- Krivonos, E.** 2004. "The Impact of Coffee Market Reforms on Producer Prices and Price Transmission." Policy Research Working Paper. Vol. 3358.
- Kuiper, W.E., and G.J. Thijssen.** 1996. "Determinants of Private Investment in Dutch Agriculture." *European Review of Agricultural Economics* 23(4): 455–472.
- Lee, J., and M.I. Gómez.** 2013. "Impacts of the End of the Coffee Export Quota System on International-to-Retail Price Transmission." *Journal of Agricultural Economics* 64(2): 343–362.
- Martin, W.J., and P.G. Warr.** 1993. "Explaining the Relative Decline of Agriculture: A Supply-Side Analysis for Indonesia." *The World Bank Economic Review* 7(3): 381–401.
- Martin, W.J., and P.G. Warr.** 1994. "Determinants of Agriculture's Relative Decline: Thailand." *Agricultural Economics* 11(2–3): 219–235.
- Mckay, B.Y.L., D. Lawrence, and C. Vlastuin.** 1983. "Profit, Output Supply, and Input Demand Functions for Multiproduct Firms: The Case of Australian Agriculture." *International Economic Review* 24(2): 323–339.
- McKay, A., O. Morrissey, and C. Vaillant.** 1999. "Aggregate Supply Response in Tanzanian Agriculture." *The Journal of International Trade & Economic Development* 8(1): 107–123.
- Mehta, A., and J.P. Chavas.** 2008. "Responding to the Coffee Crisis: What Can We Learn From Price Dynamics." *Journal of Development Economics* 85(1-2): 282–311.
- Mergos, G.J., and C.E. Stoforos.** 1997. "Fertilizer Demand in Greece." *Agricultural Economics* 16(3): 227–235.
- Ministerio de Agricultura y Desarrollo Rural.** 2020. *Caficultores—Programas de Extensión Cafetera*. Available at: <https://www.minagricultura.gov.co/atencion-ciudadano/preguntas-frecuentes/Paginas/Caficultores.aspx>.
- Montenegro, A.** 1995. "Economic Reforms in Colombia: Regulation and Deregulation, 1990–94." WBI Working Papers. Vol. 19692.
- Muhammad, A., J.L. Seale, B. Meade, and A. Regmi.** 2011. "International Evidence on Food Consumption Patterns: an Update Using 2005 International Comparison Program Data." Technical Bulletin 1929. United States Department of Agriculture (USDA).
- Muñoz-Mora, J.C., S. Tobón, and J.W. D'Anjou.** 2018. "The Role of Land Property Rights in the War on Illicit Crops: Evidence From Colombia." *World Development* 103(1): 268–283.
- Muñoz Ortega, L. G.** 2014. "Caficultura Sostenible, Moderna y Competitiva." *Ensayos de Economía Cafetera*. Vol. 30.
- Ng, S., and P. Perron.** 1995. "Unit Root Tests in ARMA Models with Data-Dependent Methods for the Selection on the Truncation Lag." *Journal of the American Statistical Association* 90(429): 268–281.
- Ng, S., and P. Perron.** 2001. "Lag Length Selection and the Construction of Unit Root Tests with Good Size and Power Published." *Econometrica* 69(6): 1519–1554.
- Ocampo-Gaviria, J.A., and C.A. Romero-Baquero.** 2015. "La Búsqueda, Larga e Inconclusa, de un Nuevo Modelo (1981–2014)." in Jose Antonio Ocampo-Gaviria (ed.), *Historia Económica de Colombia* (pp. 341–418). Bogotá: Fondo de Cultura Económica.

- Ocampo-Lopez, O.L., and L.M. Alvarez-Herrera.** 2017. "Tendencia de la Producción y el Consumo del Café en Colombia." *Apuntes Del CENES* 36(64): 139–165.
- Office of the High Peace Commissioner.** 2017. *Final Agreement to End the Armed Conflict and Build a Stable and Lasting Peace*. Bogota, Colombia: Office of the High Peace Commissioner.
- Perron, P.** 1989. "The Great Crash, the Oil Price Shock, and the Unit Root Hypothesis." *Econometrica* 57(6): 1361–1401.
- Perron, P., and T.J. Vogelsang.** 1992. "Nonstationarity and Level Shifts with an Application to Purchasing Power Parity." *Journal of Business and Economic Statistics* 10(3): 301–320.
- Pierre, G., and J. Kaminski.** 2019. "Cross Country Maize Market Linkages in Africa: Integration and Price Transmission Across Local and Global Markets." *Agricultural Economics* 50(1): 79–90.
- Pirolì, G., P. Ciaian, and D. Kancs.** 2012. "Land Use Change Impacts of Biofuels: Near-VAR Evidence From the US." *Ecological Economics* 84(1): 98–109.
- Rettberg, A.** 2010. "Global Markets, Local Conflict: Violence in the Colombian Coffee Region After the Breakdown of the International Coffee Agreement." *Latin American Perspectives* 37(2): 111–132.
- Reziti, I., and A. Ozanne.** 1999. "Testing Regularity Properties in Static and Dynamic Duality Models: The Case of Greek Agriculture." *European Review of Agriculture Economics* 26(4): 461–477.
- Rezitis, A.N., and K.S. Stavropoulos.** 2011. "Price Volatility and Rational Expectations in A Sectoral Framework Commodity Model: A Multivariate GARCH Approach." *Agricultural Economics* 42(3): 419–435.
- Richani, N.** 1997. "The Political Economy of Violence: The War-System in Colombia." *Journal of Interamerican Studies and World Affairs* 39(2): 37–81.
- Saab, B.Y., and A.W. Taylor.** 2009. "Criminality and Armed Groups: A Comparative Study of FARC and Paramilitary Groups in Colombia." *Studies in Conflict & Terrorism* 32(6): 455–475.
- Sadoulet, E., and A. De Janvry.** 1995. *Quantitative Development Policy Analysis*. Baltimore, Maryland: Johns Hopkins University Press.
- Saenz, M., and A.G. Barilla.** 2020. "Identifying New Approaches for U.S. Drug Policy Using Ownership, Location, and Internalization Factors." *Review of Economic Analysis* 12(3): 271–319.
- Sánchez-Cuervo, A.M., and T.M. Aide.** 2013. "Consequences of the Armed Conflict, Forced Human Displacement, and Land Abandonment on Forest Cover Change in Colombia: A Multi-Scaled Analysis." *Ecosystems* 16(6): 1052–1070.
- Serra, T.** 2015. "Price Volatility in Niger Millet Markets." *Agricultural Economics* 46(4): 489–502.
- Shigeto, S., L. Hubbard, and P. Dawson.** 2008. "On Farmland Prices and Rents in Japan." *Agricultural Economics* 39(1): 103–109.
- Statacorp LLC.** 2017. *Stata Time-Series Reference Manual. Release 15*. College Station, Texas: Stata Press.
- Statistics Online Support (SOS).** 2015. *Degrees of Freedom*. Department of Statistics and Data Sciences, The University of Texas at Austin. Available at: <https://sites.utexas.edu/sos/>.
- Sun, L., L.E. Fulginiti, and E.W.F. Peterson.** 2007. "Accounting for Agricultural Decline with Economic Growth in Taiwan." *Agricultural Economics* 36(2): 181–190.
- Tambi, N.E.** 1999. "Co-Integration and Error-Correction Modelling of Agricultural Export Supply in Cameroon." *Agricultural Economics* 20(1): 57–67.
- Tiffin, R., and X. Irz.** 2006. "Is Agriculture the Engine of Growth?" *Agricultural Economics* 35(1): 79–89.
- Vasavada, U., and K. Cook.** 1996. "Short-Run Dynamics of Machinery Demand in Canadian Agriculture." *Canadian Journal of Agricultural Economics* 44(2): 139–150.
- Villeza-Becerra, P.A., and C.R. Shumway.** 1992. "Multiple-Output Production Modeled with Three Functional Forms." *Journal of Agricultural and Resource Economics* 17(1): 13–28.
- Wang, S.L., and L. McPhail.** 2014. Impacts of Energy Shocks on US Agricultural Productivity Growth and Commodity Prices—a Structural VAR Analysis. *Energy Economics* 46(1): 435–444.
- Weliwita, A., and R. Govindasamy.** 1997. "Supply Response in the Northeastern Fresh Tomato Market: Cointegration and Error Correction Analysis." *Agricultural and Resource Economics Review* 26(2): 247–255.
- World Bank.** 2003. *Colombia: Coffee Sector Study 2002*. Washington, D.C.: World Bank.
- World Bank.** 2019. *World Development Indicators*. Available at: <https://datacatalog.worldbank.org/dataset/world-development-indicators>.

- Würrichhausen, N., R. Ihle, and S. Lakner.** 2015. "Price Relationships Between Qualitatively Differentiated Agricultural Products: Organic and Conventional Wheat in Germany." *Agricultural Economics* **46**(2): 195–209.
- Yavapolkul, N., M. Gopinath, and A. Gulati.** 2006. "Post-Uruguay Round Price Linkages Between Developed and Developing Countries: The Case of Rice and Wheat Markets." *Agricultural Economics* **34**(3): 259–272.
- Zivot, E., and D.W.K. Andrews.** 1992. "Further Evidence on the Great Crash, the Oil-Price Shock, and the Unit-Root Hypothesis." *Journal of Business and Economic Statistics* **10**(3): 251–270.