Cross-border Effects: Tracing U.S. Fentanyl's Effect on Rural Colombian Income

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Complaints from rural farmers in Colombia have suggested a decline in agricultural income from cocaine. This is contemporary to the rising overdose mortality rates from synthetic opioids in the U.S., hinting at a potential substitution of cocaine and fentanyl. Evidence from rural incomes has so far been scarce, given the illegal nature of the market and the response bias of farmers in government income surveys. This brief report uses luminosity data from satellite imagery as a proxy of economic activity in rural Colombian areas for a selection of regions with high concentrations of coca plants.It does so by focusing on different settlement sizes to disentangle effects on different village sizes. The demand for fentanyl in the U.S. has negatively affected *small* and *medium* sized communities in Colombia from 2012 to 2021. This potentially presents a window of opportunity for development policies in rural Colombia.

Rural | Development | Drugs | Cocaine | Fentanyl

Colombia has long been the top global producer and exporter of cocaine, averaging $1,643km^2$ of coca crops from 2015-2022 (1). From 2013-2021, production of *pasta de coca*[*] experienced an increasing trend driven by the cultivation of coca in eleven states and by the historical development of a robust, politically supported illegal market (2).

Yet, the development of the drug market in Colombia has reached a standstill, signalled by the rising social pressures from the rural sector (3). We anticipate that the primary income driver for a subset of Colombian rural households is the financial influx from the cocaine market. Preliminary assessments of rural incomes in Colombia confirm a consistent trend, particularly in regions with high coca cultivation (4). Given the importance of the returns from coca cultivation, if the demand for cocaine decreases[†], *ceteris paribus*, these farmers (*campesinos*) should experience a decrease in their income.

The U.S. has historically been the primary destination of cocaine trafficked from Colombia (6)(7). However, synthetic opioids have seen their U.S. consumption increase exponentially in the past two decades, and in 2014, fentanyl deaths surpassed cocaine-related deaths. The fentanyl deaths faced between 2015 and 2021 a 7.5-fold increase (**Figure 1**). A potential consequence of the increased fentanyl consumption is the decline of incomes for those households who produce drugs that compete with synthetic opioids: in Mexico, producers of opium poppy have been affected (8) and, aligned with the purposes of this study, Colombian farmers seem to be experiencing a reduction in their income as well (3).

The current literature potentially tells us about the structure of drug markets in South America, but the relationship between a U.S.-originated demand shock and the specific Colombian supply has rarely been central to it. In this study, we ask: "To what degree does the consumption of fentanyl contribute to the decrease in rural incomes derived from cocaine production in Colombia?". Assessing this association shapes our understanding of Colombia's and comparable countries' drug production systems, as well as sheds light on the cross-border narcotic market interconnectivity and the socioeconomic structure.

The supply side and the demand side of illegal markets in remote areas: a concern for social models

Given the illegal nature of drug consumption and production, data on it is limited, and official sources are not necessarily reliable.

[*] Putumayo, Norte de Santander, Nariño, Cauca have the highest concentration of coca plants.
[†] The wholesale cocaine prices remained largely constant throughout the period (5).

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A. Supply side. We look for non-standard hard measures of rural incomes in Colombia, different from the income survey administered by the government (*GEIH* (4) (see *Materials and Methods*) for rural households of the eight regions considered. This is motivated by our belief that households are unlikely to declare income streams originating from illegal activities truthfully. The proxy considered is *nightlight brightness* (9), measured by the VIIRS satellite, and aggregated from nightly to monthly measures via an algorithm correcting for nightly variances in weather, e.g., cloud cover (see *Materials and Methods*). Satellite images have been previously used in research in Colombia (10).

For each data point, a light intensity value is available every month for the studied period; monthly fixed effects are used to account for seasonal differences. The labels of *small*, *medium*, and *large* settlements are associated with each datapoint based to Zhang's classification ranges and our analysis of the data [‡] (9). We expect ex-ante to see more discernible changes in the economic activity of *small* communities, given that they are mainly located in rural settings, i.e., where the drug market constitutes a main source of income.

B. Demand side. No direct measures of drug consumption on a monthly basis are available. Although advances have been made in measuring drug consumption using wastewater (11), no long-time data is available for the U.S. Thus, drug consumption is proxied by *mortality* data which is available from the National Center for Health Statistics (12). Given the research question, the analysis is conducted on the deaths whose cause is solely attributed to fentanyl, excluding deaths related to both fentanyl and cocaine [§]. Using mortality as a proxy seems justified as it correlates highly with several other drug consumption indicators (14).

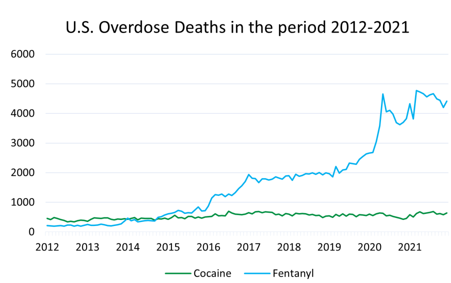

Fig. 1. Total monthly deaths for cocaine overdose only (T40.4) (green line) and fentanyl overdose only (T40.5) (blue line).

Results

To shed light on potential relationships between U.S. consumption of fentanyl and its effects on the Colombian rural economy, regressions were conducted on observations from 2012-2021 (*full sample*) and October 2014-2021 [¶] (*sub-sample*). The results of the OLS regressions are shown in **Table 2**.

[‡] small if the luminosity emanated nightly is between 0.6 nW/cm2/sr and 3, medium between 3 and 10, and large if greater than 10 in 2014.

[§] CDC's code for fentanyl is T40.5, for cocaine it is T40.4(13)

[¶] Light intensity data are available from 2012. 2014 is the year in which fentanyl deaths surpassed cocaine.

First, only fentanyl-related overdose deaths are taken as the regressor (*Columns(1)-(4)*). When considering income from the *GEIH* dataset (see *Materials and Methods*) (*Column(1)*), the coefficients are negative both in the *full* and *sub-samples*, but non-significant. When employing satellite data (*Columns(2)-(4)*), there is a negative and significant relationship between fentanyl-caused deaths and light intensity, i.e. economic activity., for both samples.

When adding controls (see *Materials and Methods*) (*Columns(5)-(8)*), coefficients are significant only when using satellite light data as the dependent variable. For both *medium* and *small* communities (*Columns(7)-(8)*), an increase in the number of fentanyl-related deaths is associated with a decrease in light intensity in both samples, *ceteris paribus*. Importantly, for *large* settlements, the coefficients are not significant, as expected (see *Supply Side*). As for cocaine-related deaths, a proxy for cocaine demand, the coefficients are not significant in the *full sample*. On the other hand, in the *sub-sample*, results are significant for *large* communities only (*Column(6)*), contrary to expectations. Furthermore, cocaine production, proxied by quinoa (see *Matherials and Methods*), affects positively *small* and *medium* communities in the *full sample*, while it does not have significant effects for *large* ones. Conversely, in the *sub-sample*, it does not affect *medium* ones, and, as expected, it positively affects the economy of *small* communities. For *big* communities, the effect remains unclear in the *sub-sample* as consumption and production of cocaine have opposite effects.

Table 1. Regression results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Income							
	Survey	Light Intensity			Survey	Light Intensity		
	GEIH	Big	Medium	Small	GEIH	Big	Medium	Small
Panel A: Full sample								
Log of deaths by fentanyl	-0.002	-0.446**	-0.174***	-0.064***	-0.022	-0.280	-0.157*	-0.055*
	(0.014)	(0.179)	(0.025)	(0.009)	(0.061)	(0.437)	(0.067)	(0.024)
Log of deaths by cocaine					0.172	1.312	-0.070	-0.050
					(0.096)	(0.881)	(0.119)	(0.044)
Log Estimated Coca Production					-0.012	-0.304	0.075**	0.031**
					(0.027)	(0.217)	(0.029)	(0.009)
Observations	951	936	936	936	840	819	819	819
R-squared	0.481	0.694	0.523	0.460	0.551	0.838	0.582	0.525
Controls	×	×	×	×	✓	✓	✓	✓
State F.E.	✓	✓	✓	✓	✓	✓	✓	✓
Month F.E.	✓	✓	✓	✓	✓	✓	✓	✓
Panel B: Sub sample								
Log of deaths by fentanyl	-0.019	-1.044*	-0.303***	-0.112***	-0.111	-0.785	-0.326***	-0.120***
	(0.020)	(0.446)	(0.029)	(0.010)	(0.101)	(0.904)	(0.065)	(0.024)
Log of deaths by cocaine					0.127	2.431*	0.079	0.018
					(0.110)	(1.081)	(0.112)	(0.042)
Log Estimated Coca Production					-0.018	-0.374**	0.038	0.015*
					(0.015)	(0.143)	(0.024)	(0.006)
Observations	690	696	696	696	609	609	609	609
R-squared	0.521	0.721	0.603	0.567	0.607	0.861	0.606	0.575
Controls	×	×	×	×	✓	✓	✓	✓
State F.E.	✓	✓	✓	✓	✓	✓	✓	✓
Month F.E.	✓	✓	✓	✓	✓	✓	✓	✓

Note: This table reports the regression results using four proxies for income (Survey (GEIH), Light Intensity (small, medium, large)). Columns (1)-(4) report the regression without including the control vector, while columns (5)-(8) show the results with controls. Panel A considers the full sample, while panel B uses the *sub-sample* starting from October 2014. All regressions include time and state-fixed effects. Standard errors are clustered by state. The unit of observation is a state-month composite. *** p<0.01, ** p<0.05, * p<0.1.

Discussion

Our results suggest that income is negatively related to the consumption of fentanyl, i.e., the increasing demand for fentanyl in the U.S. has negatively affected the economic activity of *small* and *medium* settlements in Colombia.

As expected, the insignificance of the coefficients, when using the *GEIH* survey, points towards farmers' biases when providing income information. Also, the decision to categorize areas provided important insights into Colombia's socioeconomic structure. The sign and significance of the control variables can be interpreted as a consistency check for the model specification proposed. Bearing our results in mind, further studies on the potentially forced migrations from rural to urban areas due to the decreased economic rural activity are encouraged. Furthermore, recent information on the shift from illegal plantation to illegal mining is surfacing (15). Not only can this shift serve as a rich study setting, but it also presents itself as an ideal window of opportunity to promote national solutions.For Mexico, crop substitution and opium legalisation were proposed as solutions to the opium crisis (8), increasing the potential external validity of our model.

Materials and Methods

Data. Data has been compiled for every variable from 2012-2021, at least. Data for rural income was retrieved from the national survey of Colombia, the *Gran Encuesta Integrada de Hogares (GEIH) (4)*. We matched information on income with nightlight estimates from the Earth Observation Group (16). The variables related to the number of deaths caused by fentanyl and by cocaine, were processed from data retrieved from the National Vital Statistics System of the National Center for Health Statistics and accessed via the NBER website (12). For coca production, due to the lack of complete monthly information - available on a yearly basis only – and given the fact that quinoa and coca have similar cultivation characteristics (17)(18), quinoa production is used to generate estimates for monthly coca production. The other covariates selected are the *CPI* (Consumer Price Index) to assess households' purchase parity, *Participation Rate* to control for the potential transition from being a coca paste producer to entering the legal labor market; *ENSO index* to control for extreme weather events; *Economic Performance Index* to control for the national business cycle; COVID-19 *dummy variable* to isolate the effect of the lockdown (April-June 2020) on deaths and income for the U.S. and Colombia.

Model. The technique employed to assess the relationship between rural income in Colombia and fentanyl consumption in the U.S. is a multiple regression model: $y_{it} = \beta_1 FentCon_t + \beta X_{it} + \delta_t + u_i + \varepsilon_{it}$, where y_{it} is the income of state i at month t, $FentCon_t$ is the U.S. fentanyl consumption at month t proxied by the number of deaths caused by fentanyl, X_{it} is the control variable vector described in the data section, δ_t and u_i account for time and state fixed effects respectively, and, lastly, ε_{it} is the error term. When using the *GEIH* survey, the model is structured as a log-log; when using light satellite data, the models are linear-log instead. Heteroskedasticity-robust SEs are estimated with the Eicker-Huber-White-Sandwich estimator clustering by state.

Further Research

The data suggests that US fentanyl consumption has a negative impact on rural Colombian income. However, the exact mechanism behind this effect remains unclear. One potential factor is the market power of the actors involved in the cocaine production and distribution chain, which determines how the value added is shared among them. To identify these mechanisms, more data and finer spatial resolution of nightlight data are needed, as well as more accurate information on coca production and population density. This would reduce the *noise* and help identify where the value added is concentrated (e.g., distribution hubs or rural farmers).

Experimental methods could be employed to establish causal relationships by comparing Colombia with countries facing similar challenges, e.g. Bolivia or Peru for cocaine and Mexico for heroin (poppy flowers).

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