Coffee Price Shock and Local Economic Growth: Evidence from Colombia

Raúl Velilla* Alexandre Bragança†

Abstract

This study provides evidence of how commodities price shocks affect local economic activity in Colombia. As identification strategy, we exploit the interaction between international coffee prices that affect the local economic growth differentially across municipalities that have a different intensity in coffee production. Using satellite images of light density at night as a proxy of local economic activity, we document a positive and strong effect of coffee price shock on local economic outcome. We also examine some potential channels by which this association may have played out. We document that more illuminated areas report better schooling outcomes and a reduction in mortality. Our findings help to understand the economic dynamic in an accurate way at a sub-national level in Colombia, where data about GDP at municipality level are not available.

JEL codes: Q17; E01; O11.

Keywords: Nighttime Light; GDP; developing country.

Resumo

Este estudo fornece evidências de como os choques nos preços de commodities afetam a atividade econômica local na Colômbia. Como estratégia de identificação, explorou-se a interação entre os preços internacionais do café que afetam o crescimento econômico local diferencialmente entre os municípios que têm intensidade diferente na produção de café. Usando imagens de satélite de densidade da luz noturna como uma proxy da atividade econômica local, documentou-se um efeito positivo e significativo do choque do preço do café sobre a produção local. Também examinou-se alguns canais potenciais pelos quais essa associação pode ser explicada. Documentou-se que áreas mais iluminadas refletem melhores resultados escolares e redução na mortalidade. Tais descobertas ajudam a entender a dinâmica econômica de maneira precisa em nível subnacional na Colômbia, onde os dados sobre o PIB em nível municipal não estão disponíveis.

Classificação JEL: Q17; E01; O11.
Palavras-chaves: Nighttime Light; PIB; país em desenvolvimento

Área 12 - Economia Social e Demografia Econômica

*Universidade Federal de Viçosa. E-mail: raul.gomez@ufv.br.
†Universidade Federal de Viçosa. E-mail: acoelho@ufv.br.

1 Introduction

Many studies have investigated the effects of commodity price shocks on the economic activity at the national level in both developed and developing countries (see e.g., Chen and Nordhaus, 2011; Michaels, 2011; Acemoglu et al., 2013; Caselli and Michaels, 2013, among others). Although the Gross Domestic Product (GDP) is a traditional indicator used to analyze these effects, the researchers usually have to deal with some inconsistent and bias that could arise in their estimated results. This is due to the fact that GDP itself is often inadequately measured, mainly in developing countries (Henderson et al., 2012). In contrast, few papers have analyzed whether these effects vary at a more disaggregated level. The difficulty in this type of analysis is related to the unavailability of data at the subnational level, official authorities in developing countries often do not have the infrastructure and resources to generate accurate statistical data on GDP.

This paper studies these questions by examining the effects of shock in coffee prices on the local economic growth in Colombia measured as intensity of night-lights[1]. We do this by exploiting the variation in international coffee prices, which enable us to assess how the changes in the economic environment affected the Colombian municipalities' economic growth among 1992-2005. In particular, we focus the period between the years 1994-1997, in which internal coffee prices increased sharply as a consequence of a frost episode in Brazil.

The use of luminosity data as a proxy of economic activity has been documented and tested in the pioneering work by Henderson et al. (2012). We could expect that most human activities in the evening, represented as more consumption and more production, required more artificial lights. This could be understood because the majority of goods used at night need lights. Therefore, we could assume that regions with more light intensity are regions with more economic activity (Elvidge et al., 1997; Doll et al., 2006; Chen and Nordhaus, 2011). Consequently, we would expect that its income to be higher (Henderson et al., 2012; Lessmann and Seidel, 2017). In this order of ideas, it seems reasonable to assume that night-lights can be used as a proxy of GDP for regions where data are poorly measured or data are not available. To shed a light on this hypothesis, we provide consistent evidence on the relationship in our empirical application at the subnational level in Colombia[2].

The use of luminosity data is attractive for several reasons. First, this data could help to deal with potential problems of no availability or little reliability that plague official data in developing countries (Henderson et al., 2012; Chen and Nordhaus, 2011; Sutton et al., 2007). Colombia is an example of this lack of information and data on GDP at municipality level does not exist[3]. Second, luminosity data are available over time and for all places on Earth with uniform measure and over the very fine level of

[1] Other measures of economic activity have been used as proxies of GDP such as electricity consumption. However, electricity consumption often are not available for many countries at sub-national level. In the case of Colombia, electricity consumption information are not available over time and at the municipality level

[2] For a first view of the validity of this hypothesis, Figures A1 and A2 in the appendix show a plot of log GDP and log lights for the country as a whole and at the department level. We can observed a strong and positive relationship.

[3] To the best of our knowledge, the most disaggregate data on GDP that at available in Colombia is at the department level. Department are analogous to states in the United State.

resolution. Finally, even though potential problems concerning measurement errors can appear, related to how the satellite captures the lights, or climatic conditions, or human culture in the use of lights, this kind of measurement errors are not correlated with traditional GDP data errors (Pinkovskiy and Sala-i Martin, 2016).

Our identification strategy compares the night-lights intensity of producing and non-producing municipalities before and after coffee price shocks in a difference-in-difference approach. This analysis is important in the sense that it can suggest to the governments to encourage (or to discourage) the agricultural sector in specific municipalities. We find differential and statistically significant increases in the night-lights intensity in municipalities that produce more coffee when the price rises exogenously. In particular, the estimated coefficient from our preferred specification reports an elasticity in coffee price shocks of 0.20, which represent an increase of 0.26 percent relative to the baseline mean. We also show that our results are robust with respect to a different specification. In particular, we confirm that the results are robust with respect to control for municipality and year fixed effects, municipality-specific linear time trends, different cluster specifications as well as to control by a set of socio-economic characteristic of municipalities. Furthermore, we obtain similar results when we used different night lights density measures.

Having documented that the coffee price shock have a strong and robust effect on nighttime lights, we then present suggestive evidence for some potential mechanisms through which the coffee price shock may be have affect the nighttime density. We focus on two factors that have been traditionally linked by the literature with to local economic conditions: schooling and mortality rates. First, we use the 2005 Colombian Demographic Census to construct the average of years of education by municipalities for the population with 25 or more years old and then we estimate the link between light nigh intensity and years of education. The estimates suggest that in areas with greater luminosity reflect higher years of education. Consistent with our results, there is some evidence showing that geographic units (counties, states, countries) with better economic condition reflect as more school resources have a positive effect on years of education (see e.g., Case and Deaton, 1999; Duflo, 2001; Paxson and Schady, 2002; Card and Krueger, 1996)

Second, using data about vital statistic from the Colombian National Administrative Department of Statistics (DANE), we construct the mortality rate of each municipality. Then, we estimate our preferred specification using mortality rate as dependent variable. A reduction of the mortality variable could be interpreting as an increase in survival chances, which could be reflect better economic conditions in that specific area. We show that an increase of 1 percent in our coffee shock variable is associated with and decrease in the mortality rate.

This paper is related to a large literature that uses satellite images as a proxy of economic activity (see e.g., Pinkovskiy and Sala-i Martin, 2016; Alesina et al., 2016; Michalopoulos and Papaioannou, 2013; Henderson et al., 2012, among others). For example, Michalopoulos and Papaioannou (2013) use luminosity data to investigate the role of deeply rooted pre-colonial ethnic institutions over regional development in Africa. Alesina et al. (2016), in its turn, construct measures from luminosity data in order to investigate the consequences and origins of ethnic inequality. Specifically, they find evidence of those geographic endowments between ethnic countries that could explain inequality. Pinkovskiy and Sala-i Martin (2016) use nighttime lights as tools in order to show how much weight is necessary to give to national accounts GDP per capita and household surveys to obtain a better predictor of income. They find that the best predictor of the log of true income must receive nearly 100% of the weight on GDP per capita.

Our work is also related to the voluminous literature that assesses the effects of macroeconomic shocks on several local economic variables (see e.g., Acemoglu et al., 2013; Monteiro and Ferraz, 2010; Vizcaino, 2017; Carreri and Dube, 2017, among others). Acemoglu et al. (2013), for example, using oil price shocks as an instrument for income, assess the changes in health spending in the southern United States. Vizcaino (2017), using a similar empirical strategy, documents that a gold boom has a positive and statistically significant impact on birth outcomes in Colombian children. Monteiro and Ferraz (2010), in its turn, analyzing how the increase in Brazil's oil production affect local democracy find that royalty payments produce a large incumbency in the short-term.

Most closely related to our study are the contributions of Dube and Vargas (2013), Miller and Urdinola (2010) and, Santos (2018). Dube and Vargas (2013), for example, show how the commodities price shocks have an effect on armed conflict in Colombia. More specifically, the authors document that changes in the price of agricultural goods are negatively related to violence, while changes in the price of natural resources are positive. Meanwhile, Miller and Urdinola (2010), exploiting world coffee price fluctuations in order to examine the cyclical nature of infant and child mortality in Colombia, find a procyclical relationship in child death. Finally, Santos (2018) analyzing the gold boom found a decrease in local unemployment by 3.5% in the short term in Colombia. To the best of our knowledge, the present study is the first to exploit a quasi-experimental design to empirically investigate the relationship between coffee price shocks and a more accurate measure of local economic growth (night-lights density) in Colombia. As a product of this analysis, our findings also contribute with a new estimation of economic growth for Colombia at the municipality level.

The rest of this paper is structured as follows. Section 2 briefly reviews the Colombian coffee market. Section 3 describes the data and how our variables were constructed. Section 4 presents the empirical strategy. Section 5 provides the main results and robustness tests. Finally, section 6 concludes.

2 Background

Colombia is well known for being one of the largest coffee producers in the world. During the largest part of the century XX, the Colombian economy is being associated with coffee production, which has played an important role in the development and economic growth of the nation (Cárdenas et al., 1997). Most coffee production in Colombia is concentrated in the mountainous region, at the departments of Antioquia, Caldas, Quindio, and Risaralda. The altitude in this region ranging from 1000 to 2100 meters, and the average temperature varying between 18 and 22 degrees Celsius. Rainfall is frequent with measure approximately of 1500 to 2000 millimeters. In some regions, according to its geographic characteristics, coffee can be produced during all year in two harvests. The main harvest is carried out between October and December, and the second between April and May. We will take advantages of this environment conditions in our empirical strategy.

Colombian coffee sector is known to be, over the period of our analysis (1992-2005), the most important agricultural sector. There are several reasons that could understand this importance. First, coffee has been the second largest export commodity during the decades of the 90s. Its participation in the total GDP and the agricultural GDP are about 1.7 and 23.9 percent between 1995 and 1999, respectively (Giovannucci et al., 2002). Second, Colombian coffee cultivation employs the largest number of workers than in other agricultural sectors. Specifically, at the beginning of the 90s, the coffee sector represented near to 34 percent of the agricultural employment, which could be translated in a 750 thousand full-time jobs (Junguito and Pizano, 1991). Finally, incomes of about 18 percent of rural households depend directly on coffee production in 1997 (Giovannucci et al., 2002). This dependence is associated either with the benefits for crops or wages labor. Given the importance of this sector, the favorable environment condition that is necessary for coffee cultivating and the high quality and availability of data, the study of the coffee market becomes very attractive.

3 Empirical strategy

The empirical strategy follows a difference-in-difference estimator and seeks to examine whether changes in international coffee prices have a different impact in areas that are more suitable to produce more coffee on local economic growth measured as the night-lights intensity. Thus, with the objective of obtaining the causal effects, we could compare the intensity of the light in producing and non-producing municipalities before and after the shock of prices. In particular, our variable of interest is the interaction between the log of average annual of international coffee prices and the intensity of coffee production in each municipality in 1997. Thus, we can interpret this variable as our measure of exposition to the price variation or macroeconomic shocks.

Two potential endogeneity problems could threaten the validity of our empirical strategy. On one hand, we could face coffee price endogeneity due to Colombia rank as the second exporter during a large part of our time of study and this could have an influence on international coffee prices (Dube and Vargas, 2013). Following Dube and Vargas (2013), we address this concern using data on the export volume of Brazil, Indonesia, and Vietnam, the other three major coffee producers, as an instrument for the internal coffee price. On the other hand, coffee production could be endogenously determined because we do not have a measure of the production of this commodity at the beginning of our period of studies. To deal with this issue, we follow the strategy proposed by Dube and Vargas (2013), and instrumentalize coffee intensity with rainfall and temperature for each municipality[4]. Rainfall and temperature could be excellent candidates for instruments due to the fact that geographic conditions of each municipality determine which are more suited to produce coffee[5].

[4]See Miller and Urdinola (2010) for a similar approach.

[5]See section 2 for details about these conditions. Temperature and rainfall data come from Dube and Vargas (2013).

Formally, we can carry out the estimation in two stages. The second stage can be specified as:

$$l_{mdt} = \alpha_m + \rho_d + \lambda_t + \mu_m \times t + \beta(Coffee_{md} \times logPCoffee_{avt}) + \Phi Z_{mdt} + \varepsilon_{mdt} \quad (1)$$

where l_{mdt} is the log of the sum of luminosity intensity in the municipality m, department d, and year t; $Coffee_{md}$ represents a measure of land destined to coffee production in 1997 for each municipality; $logPCoffee_{avt}$ represents the annual average of the natural log of the international coffee prices. The vector Z including time-varying controls, like the natural log of population, that are included in some our specifications. The model also include municipality fixed effects (α_m) and department fixed effects (ρ_d), which absorb any unobservable time-invariant factors between municipalities and department such as geographic characteristics that could confounder de coefficient. We also include year fixed effects (λ_t), which captures aggregate shocks impacting the entire country but that can change over time. The term ε_{mdt}, in its turn, is the idiosyncratic error term. Finally, we also control for specific-municipality linear tends $\mu_m \times t$ to take into account possible factors changing over time that might affect the outcome of interest.

The first stage for coffee, in its turn, can be represented as:

$$Coffee_{md} \times logPCoffee_{avt} = \alpha_m + \rho_d + \lambda_t + \mu_m \times t + \sum_{h=0}^{1}\sum_{n=0}^{1}(R^m_{jr} \times T^n_{jr} \times FE_t)\theta_{hn} + \Phi Z_{mdt} + \xi_{mdt} \quad (2)$$

where R^m_{jr} is the average annual rainfall of municipality m of department d raised to the power h; T^n_{jr} is the average annual temperature of municipality m of department d raised to the power n; $\theta_{hn} = 0$; FE_t is the log coffee export volume of Vietnam, Brazil, and Indonesia; all exogenous variables considered in the second stages are included in this stage also. Our main estimation uses 2SLS and all our models use robust standard errors for clustering at the department level to control for potential serial correlation (Bertrand et al., 2004).

The parameter of interest is in the equation (1), which show us the differential impact of coffee price shock on the economic growth in municipalities that cultivate more coffee. The key identifying assumption of our approach is that in the absence of coffee price shocks, municipalities with different coffee production have experienced the same proportional changes in light-nights intensity. We also exploit the fact that this commodity is not uniformity distributed all over the country. In fact, its distribution depends on demographic characteristics (temperature and rainfall) as we have mentioned before. Therefore, we can assume that any effects of coffee price shocks are randomly assigned. Thus, any changes in the proxy of the intensity of coffee cultivation are not correlated with our measurement of economic activity, once we have controlled for all independent variables.

4 Data

4.1 International Coffee Prices

This paper constructs a time series data on the international coffee prices form the International Coffee Organization. The data correspond to the period of 1992 until 2005. The focus of our study is between 1994 to 1997, the period in which the coffee price increased exogenously as a consequence of a frost episode in Brazil that produced a substantial harvest loss[6]. Figure 1 shows the time series of average annual of international coffee prices[7]. We can visualize the three peak that we mentioned before. Specifically, focus on our period of study, coffee prices rose dramatically of $1.53 per kilogram in 1993 to a high of $4.17 per kilogram.

[Figure 1 approximately here]

4.2 The intensity of Coffee Production

The National Federation of Coffee Growers (NFCG) had developed three censuses since its creation in 1927[8], at the beginning of the 70s, at the beginning of 80s, and the last one at the middle of 90s. For the purpose of this study, the measure of the intensity of coffee production is the number of hectares planted with coffee in each municipality in 1997, the most recent data available. We obtained this information from Dube and Vargas (2013). The final sample contains information about 966 municipalities, which correspond to 86% of total Colombia' municipalities. Figures 2 and 3 draw the geographical distribution of coffee production and the distribution of coffee intensity production at the municipality level in 1997, respectively. Note that although the coffee cultivation is concentrated on departments of Antioquia, Caldas, Quindio, and Risaralda, there is a significant dispersion among the municipalities, which show us that importance of coffee production varies substantially across the municipalities. More specifically, 549 municipalities producing coffee that is approximately 57% of our sample. Given this heterogeneity, municipalities are exposed to different changes in their economic activity. These changes will play a very important role in our empirical application.

[Figure 2 approximately here]

[Figure 3 approximately here]

[6] There are other episodes of exogenous changes in the international supply of coffee that could be exploited like frosts and drought in Brazilian's coffee harvest during 1975 and 1985, respectively; or the collapse of the International Coffee Agreement during 1989-90 (See Figure 1 for a graphic illustration). Nonetheless, the date on the intensity of night-lights, our independent variable, is only available since 1992 until 2013.

[7] Figure A2 in the appendix shows the tendency of internal coffee price for Colombia since 1990 to 2005. Again, we can observe that between 1994 and 1997 prices increased sharply.

[8] The NFCG was born with the purpose to represent Colombia coffee producers both nationally and internationally, as well as to improve the labor conditions and welfare. (See https://www.federaciondecafeteros.org/particulares/en/quienes$_somosformoredetail.$)

4.3 Nighttime light

We use luminosity intensity as our main variable of economic activity across Colombian municipalities. Data came from the Defense Meteorological Satellite Program's Operational Linescan System (DMSP/OLS) provided by the National Oceanic and Atmospheric Administration's (NOAA) since the 1970s. We use data from 1992 to 2005 due to its digital availability[9]. Each satellite observes each place on Earth every night between 8:30 to 10:00 pm local time. The data are collected and saved in a digital number (DN), which ranged from 0 to 63 with a resolution of 30 arc-second area pixel, or approximately 0,86 square kilometers at the equator[10]. The dataset covering 75N to 65S latitude and 180W to 180 longitude. The data are processed overlaying all daily images obtained during the calendar year, removing ephemeral lights like lightning and forest fires, those light that are shrouded by cloud or overpowered by the aurora or solar glare (near the poles), and other factors that can confound the results. Figure 4 illustrates graphically how the night-lights intensity evolved over Colombia in 1992 and 2005. We can observe that the intensity of the lights increased significantly in many municipalities already illuminated as well as in some municipalities unlit in 1992. In general, the sum of the night-lights intensity rose in mean by 4.09% during this period.

We use a raster calculator tool to construct our proxy of GDP. Specifically, we sum up all the digital numbers across pixels for each Colombian municipalities for each year[11].

$$light_{mdt} = \sum_{i=0}^{63} \times (\# \ of \ pixels \ in \ municipality \ m, \ department \ d, \ and \ year \ t \ with \ DN = i) \tag{3}$$

This measure of night-lights intensity has been frequently used to construct indexes over countries and year in this kind of literature. Following Henderson et al. (2012), we take the natural log of this sum in order to construct our main dependent variable.

[Figure 4 approximately here]

4.4 Gross Domestic Product (GDP)

As we have mentioned before, the disaggregated national account in developing countries is unavailable or available with poor quality. In Colombia case, GDP data only are available at national and department level. We use data on GDP at the national level from the World Bank from 1992 to 2005. Meanwhile, department GDP data come from Departamento Administrativo Nacional de Estadística (DANE for its acronym in Spanish), which there are available only since 2000.

[9]Six sensors have collected this time series of DMSP/OLS nighttime lights for the period of 1992-2013: F10 (1992-1994); F12 (1994-1999); F14 (1997-2003); F15 (2000-2007); F16 (2004-2009), and F18 (2010-2013).

[10]Note that the luminosity intensity ranking between 0 and 63, where a value of 0 mean no light and 63 the largest luminosity.

[11]Other measures are calculated like mean, median and, standard deviation of night-lights density. We use these measures in auxiliary regression as robust tests. In this article, we present this estimation on standard deviation, others estimations are available on request.

4.5 Census Data

In our analyses we use a set of municipality's characteristic in order to provide robustness to the results. This data from the 1986, 1993 and 2005 Colombian census, which are available through the Integrated Public Use Micro Sample (IPUMS)[12]. The IPUMS data provide demographic and socioeconomic information about 10 percent of individuals randomly extract to the original census. The information are weighted in order to preserve the representativeness. For our purpose, we construct the average weighted of years of schooling, which we use as dependent variable in our mechanism section. In this exercise, We limit the sample to individuals over 25 years old, which probably their schooling decisions have already finished. On the other hand, we construct the data about the number of household with electricity and water supply and we include as a control variable in our main results.

5 Results

5.1 A first overview of the data.

Table 1 displays the descriptive statistics for producing and non-producing municipalities separately. One feature of potential interest are the values in the row that summarize the changes in light density at night between treatment and control group before and after macroeconomic shock. In general, we can observe that on both non-coffee and coffee producer municipalities the night-lights intensity increased. On average, the sum of the light intensity of non-producer municipalities passed from 940.60 to 983.90, while coffee producer municipalities passed from 551.82 to 562.33, which represented an increase of 4.6% and 1.90%, respectively.

[Table 1 approximately here]

5.2 Relationship between Night-lights and GDP

Henderson et al. (2012) and Pinkovskiy and Sala-i Martin (2016) have documented the strong correlation between night-lights and GDP at the national level for a high set of countries. However, this relationship exists specifically for Colombia? Are the night-lights a good proxy for GDP a geographic disaggregated level? In this subsection, we investigated these questions and we brought statistical support to the strong relationship plotted in Figures A1 and A2. Specifically, using OLS estimator, we regressed the log of night-lights intensity on log GDP at the department level. The result is presented in Table 2. Our most basic specification is presented in column (1), we do not include any controls. In the next specifications, we add controls to the baseline specification. Thus, column (2) add year fixed effects, column (3) department fixed effects and, column (4) department specific linear time trends.

In overall, the coefficients in columns (1) to (4) suggest a positive and statistically significant linear relationship between log night-lights and log GDP. In addition, we can see that the estimated relationship remains very similar in its magnitude across different specification, although its significance falls from 1 percent in column (1) to 10 percent in the remains. Column (4) provides the elasticity of night-lights

[12] The IPUMS data are publicly available at https://international.ipums.org/international/.

with respect to GDP of 0.283, with a standard error of 0.148. This result is in line with previous studies developed by Pinkovskiy and Sala-i Martin (2016) who find a coefficient of 0.661 when they do a similar regression of the log light per capita on log GDP per capita[13]. Taken together, these results can bring strong support to the hypothesis that the night-lights intensity can be used as a good proxy of economic activity at a more disaggregated level (municipal level, which is the focus in our study).

[Table 2 approximately here]

5.3 Effects of Coffee Price Shocks on Night-lights Density

Table 3 reports the main regression results of the average effects of coffee price shocks on night-lights density. It also shows in detail how the estimated treatment effect varies across different specifications. In the baseline calculation, column (1), we only adjust for demographic characteristics (natural log of population and coca cultivation). Then, we in each column add a different set of controls. Thus, column (2) adjusted the regression adding region fixed effects, while column adding (3) year fixed effects. Column (4) reveals the estimated coefficient from our preferred specification. This regression incorporates all the control of the first three columns and department specific linear tends. The estimated coefficient suggests a positive and statistically different from zero effect, which suggests that the night-lights intensity of coffee producer municipalities increases more in response to coffee prices increases than coffee non-producer municipalities.

To interpret the magnitude of the estimated coefficients, we consider the coffee boom represented as the variation of the natural logarithm of coffee prices between 1994 and 1997 when coffee prices increased by 0.20 log points . We also consider the average coffee intensity of municipalities in 1997, which was 1.52 thousand hectares. Taken this together, the estimated coefficient suggests an increase of 0.014 in the natural log of night-lights density. When we compare this result with the mean of the distribution, this increase reaches up to about 0.26% in the luminosity. This result aligns with the findings in Corbi et al. (2014), who find an increase in luminosity between 1.3 and 1.5 percent when the Fundo de Participação dos Municípios (FPM for its acronym in Spanish) increase in 10 percent.

[Table 3 approximately here]

5.4 Robustness Checks

We have conducted a number of different specification check in order to investigate the robustness of the main finding. In Table 4, we estimate our main results using the average coffee intensity of municipalities from the 1980 coffee census instead of 1997, the results are essentially unchanged[14]. We find an estimate coefficient of 0.20 (standard error==0.082), which is statistically significant at the 1 percent level of significance. The magnitude of this coefficient is relatively similar to the baseline model.

[13] We also estimated this relationship using the variables in terms per capita and the results are very similar (Results are available on request).

[14] The 1980 coffee census was conducted about one decade before our period of study, we believe that this measure are not correlated with our dependent variable in the period studied. However, 1980 and 1997 coffee cultivation intensity are strongly correlated.

[Table 4 approximately here]

6 Mechanims

As showed in previous section, there is a strong and positive relationship between the shock coffee prices and night lights intensity. Nevertheless, what is behind this relationship? In this section, we try to answer this question investigating some potential channels that may explain this relationship. Specifically, we estimate our main specification (equation 1 and 2) but use variables capturing this potential mechanisms as a dependent variables. Again the variables are transformed using natural logarithm, which the estimated coefficient can be interpreted as elasticities due to our price shock variable are measured in terms of log points also. Table 5 show the results our this exercise. More specifically, the estimated coefficient suggests a positive effect of the price coffee shock on years of education and a negative effect on mortality. This results can be interpreted as a a better economic condition of the coffee producer municipalities after the increase of international coffee prices.

[Table 5 approximately here]

7 Conclusion

This paper has offered new evidence on the effects of macroeconomic shocks on local economic growth in a developing country. For this purpose, we have used a novel measure of local economic activity. In particular, we have used data of satellite images on light density at night as a proxy of GDP. This question is particularly important in developing countries where shock in commodities prices have an important influence in the local economic activity and often data at sub-national level are not available or are plagued with measurement errors. Thus, we can obtain a more accurate measure of local economic growth that allows us to have a better understanding of the welfare of the population.

We advance in the understanding of how changes in environment economic affect the local economic growth. For that, this paper exploits the boom of coffee that Colombia experimented in the middle of 90s in order to explain the economic growth measured as the intensity of artificial light at night. Using a difference-in-difference as an empirical approach, our estimates provide two important results. First, we identified that coffee producer municipalities' experienced a differential and statistically significant increase in the night-lights density compared to non-coffee producer municipalities. Our main estimate provides an elasticity in coffee price shock of 0.20 that can be understood as an increase of 0.26% in the natural log of night-lights density if we compare with the respective mean of the distribution. Second, we provide a new proxy of GDP at municipality level that could be useful for future researches once data that are not available for this country.

References

Acemoglu, Daron, Amy Finkelstein, and Matthew J Notowidigdo, "Income and health spending: Evidence from oil price shocks," *Review of Economics and Statistics*, 2013, *95* (4), 1079–1095.

Alesina, Alberto, Stelios Michalopoulos, and Elias Papaioannou, "Ethnic inequality," *Journal of Political Economy*, 2016, *124* (2), 428–488.

Bertrand, Marianne, Esther Duflo, and Sendhil Mullainathan, "How much should we trust differences-in-differences estimates?," *The Quarterly journal of economics*, 2004, *119* (1), 249–275.

Card, David and Alan B Krueger, "School resources and student outcomes: An overview of the literature and new evidence from North and South Carolina," *Journal of economic Perspectives*, 1996, *10* (4), 31–50.

Cárdenas, Mauricio, Denisse Yanovich et al., "Café y desarrollo económico: un análisis departamental," Technical Report, FEDESARROLLO 1997.

Carreri, Maria and Oeindrila Dube, "Do natural resources influence who comes to power, and how?," *The Journal of Politics*, 2017, *79* (2), 502–518.

Case, Anne and Angus Deaton, "School inputs and educational outcomes in South Africa," *The Quarterly Journal of Economics*, 1999, *114* (3), 1047–1084.

Caselli, Francesco and Guy Michaels, "Do oil windfalls improve living standards? Evidence from Brazil," *American Economic Journal: Applied Economics*, 2013, *5* (1), 208–38.

Chen, Xi and William D Nordhaus, "Using luminosity data as a proxy for economic statistics," *Proceedings of the National Academy of Sciences*, 2011, *108* (21), 8589–8594.

Corbi, Raphael, Elias Papaioannou, and Paolo Surico, *Federal transfer multipliers. quasi-experimental evidence from brazil*, National Bureau of Economic Research, 2014.

Doll, Christopher NH, Jan-Peter Muller, and Jeremy G Morley, "Mapping regional economic activity from night-time light satellite imagery," *Ecological Economics*, 2006, *57* (1), 75–92.

Dube, Oeindrila and Juan F Vargas, "Commodity price shocks and civil conflict: Evidence from Colombia," *The Review of Economic Studies*, 2013, *80* (4), 1384–1421.

Duflo, Esther, "Schooling and labor market consequences of school construction in Indonesia: Evidence from an unusual policy experiment," *American economic review*, 2001, *91* (4), 795–813.

Elvidge, Christopher D, Kimberley E Baugh, Eric A Kihn, Herbert W Kroehl, Ethan R Davis, and Chris W Davis, "Relation between satellite observed visible-near infrared emissions, population, economic activity and electric power consumption," *International Journal of Remote Sensing*, 1997, *18* (6), 1373–1379.

Giovannucci, Daniele, José Leibovich, Diego Pizano, Gonzalo Paredes, Santiago Montenegro, Hector Arévalo, and Panos Varangis, "Colombia coffee sector study," 2002.

Henderson, J Vernon, Adam Storeygard, and David N Weil, "Measuring economic growth from outer space," *American economic review*, 2012, *102* (2), 994–1028.

Junguito, Roberto and D Coordinadores Pizano, "Producción de café en Colombia Fedesarrollo-Fondo Cultural Cafetero," 1991.

Lessmann, Christian and André Seidel, "Regional inequality, convergence, and its determinants–A view from outer space," *European Economic Review*, 2017, *92*, 110–132.

Michaels, Guy, "The long term consequences of resource-based specialisation," *The Economic Journal*, 2011, *121* (551), 31–57.

Michalopoulos, Stelios and Elias Papaioannou, "Pre-colonial ethnic institutions and contemporary African development," *Econometrica*, 2013, *81* (1), 113–152.

Miller, Grant and B Piedad Urdinola, "Cyclicality, mortality, and the value of time: The case of coffee price fluctuations and child survival in Colombia," *Journal of Political Economy*, 2010, *118* (1), 113–155.

Monteiro, Joana and Claudio Ferraz, "Does oil make leaders unaccountable? Evidence from Brazil's offshore oil boom," *unpublished, PUC-Rio*, 2010.

Paxson, Christina and Norbert R Schady, "The allocation and impact of social funds: spending on school infrastructure in Peru," *The World Bank Economic Review*, 2002, *16* (2), 297–319.

Pinkovskiy, Maxim and Xavier Sala i Martin, "Lights, Camera… Income! Illuminating the national accounts-household surveys debate," *The Quarterly Journal of Economics*, 2016, *131* (2), 579–631.

Santos, Rafael J, "Blessing and curse. The gold boom and local development in Colombia," *World Development*, 2018, *106*, 337–355.

Sutton, Paul C, Christopher D Elvidge, Tilottama Ghosh et al., "Estimation of gross domestic product at sub-national scales using nighttime satellite imagery," *International Journal of Ecological Economics & Statistics*, 2007, *8* (S07), 5–21.

Vizcaino, CARLOS ANDRES CHARRIS, "EARLY EXPOSURE TO MACROECONOMIC SHOCKS: GOLD BOOM AND BIRTH WEIGHT IN COLOMBIA." PhD dissertation, Universidade Federal de Viçosa 2017.

Table 1: Descriptive Statistics

	Mun	Obs.	Mean	SD	Min	Max
Panel A : Coffee Producer						
Coffee_intensity	549	7434	1,52	1,82	0,0004	10,59
Log_popopulation	549	7686	-4,35	0,90	-6,76	-1,36
Rainfall	549	7686	1930,79	722,22	300	5910
Temperature	549	7686	21,05	3,70	11,20	28,90
Log_internalprice	549	7686	0,56	0,20	0,25	0,93
Log_top3_coffee	549	7686	3,49	0,26	3,09	3,84
Light_sum	549	7685	571,87	903,79	0,19	8122,62
Light_mean	549	7685	2,34	5,68	0,00	62,09
Light_stde	549	7685	2,51	3,32	0,01	25,80
Panel B: Non-Coffee Producer						
Coffee_intensity	417	5838	0	0	0	0
Log_popopulation	417	5838	-4,38	1,03	-8,69	-1,44
Rainfall	417	5838	1809,89	1243,26	160,00	9200
Temperature	417	5838	21,65	6,21	3,90	28,90
Log_internalprice	417	5838	0,56	0,20	0,25	0,93
Log_top3_coffee	417	5838	3,49	0,26	3,09	3,84
Light_sum	417	5838	984,99	1882,49	0,99	31097,31
Light_mean	417	5838	3,16	7,02	0,01	54,78
Light_stde	417	5838	3,16	3,99	0,03	19,96

Source: Research results.

Table 2: Relationship between GDP and Night-lights Density

	(1)	(2)	(3)	(4)
Log GDP	0.36193***	0.34192*	0.34192*	0.28337*
	(0.04211)	(0.17049)	(0.17049)	(0.14898)
Year Fixed Effects	No	Yes	Yes	Yes
Department Fixed Effects	No	No	Yes	Yes
Department-Specific trends	No	No	No	Yes
Observations	448	448	448	448
R2	0.965368	0.981515	0.981515	0.986438

Source: Research results.
Notes: The dependent variable is the natural logarithm of the sum of luminosity intensity in department d and year t. Robust standard errors clustered at department level are into parentheses. . *** p<.01, ** p<0.05, * p<.1

Table 3: Effects of Coffee Price Shocks on Night-lights Density

	(1)	(2)	(3)	(4)
CoffeeProduction1997 ×CoffeePrice	0.601***	0.748***	0.189***	0.209**
	(0.029)	(0.031)	(0.027)	(0.094)
log_population	0.249***	0.210***	0.275*	0.335
	(0.046)	(0.050)	(0.161)	(0.250)
Coca Production	0.003	-0.001	-0.004	0.002
	(0.004)	(0.005)	(0.007)	(0.008)
Region Fixed Effects	No	Yes	Yes	Yes
Year Fixed Effects	No	No	Yes	Yes
Department-Specific trends	No	No	No	Yes
Observations	13,271	13,271	13,271	13,271

Source: Research results.
Notes: The dependent variable is the natural logarithm of the sum of luminosity intensity in municipality m, department d and, year t. The effect of coffee price shock is computed by multiplying the difference in the log of price from their peak in 1997 – 1994, the coffee intensity (1.52), the estimated coefficient, and dividing the resulting value by the mean of the dependent variable. Robust standard errors clustered at department level are into parentheses. Following the strategy development by Dube and Vargas (2013), we instrumentalize the interaction of the internal coffee price and coffee production intensity by the interaction of coffee export volume of Brazil, Indonesia and Vietnam with temperature, rainfall, and rainfall multiplying with temperature. *** p<0.01, ** p<0.05, * p<0.1

Table 4: Effects of Coffee Price Shocks on Night-lights Density (Coffee Intensity 1980)

	(1)	(2)	(3)	(4)
CoffeeProduction1980×CoffeePrice	0.722***	0.788***	0.209***	0.204**
	(0.040)	(0.026)	(0.056)	(0.082)
log_population	0.312***	0.356***	0.345	0.335
	(0.046)	(0.050)	(0.161)	(0.250)
Coca Production	0.003	-0.001	-0.004	0.002
	(0.006)	(0.005)	(0.005)	(0.005)
Region Fixed Effects	No	Yes	Yes	Yes
Year Fixed Effects	No	No	Yes	Yes
Department-Specific trends	No	No	No	Yes
Observations	13,271	13,271	13,271	13,271

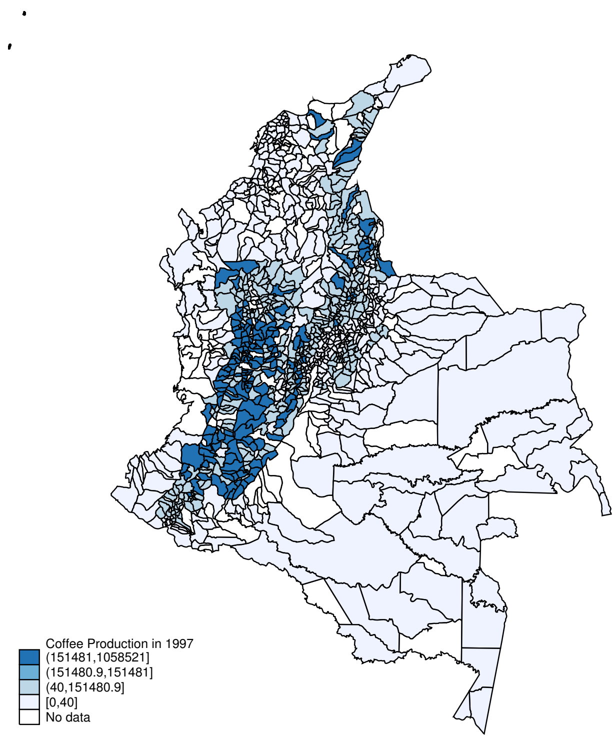
Source: Research results.
Notes: The dependent variable is the natural logarithm of the sum of luminosity intensity in municipality m, department d and, year t. The effect of coffee price shock is computed by multiplying the difference in the log of price from their peak in 1997 – 1994, the coffee intensity from 1980, the estimated coefficient, and dividing the resulting value by the mean of the dependent variable. Robust standard errors clustered at department level are into parentheses. Following the strategy development by Dube and Vargas (2013), we instrumentalize the interaction of the internal coffee price and coffee production intensity by the interaction of coffee export volume of Brazil, Indonesia and Vietnam with temperature, rainfall, and rainfall multiplying with temperature. *** p<0.01, ** p<0.05, * p<0.1

Table 5: Alternative Explanation

	Year's of Schooling	Mortality
CoffeeProduction1980×CoffeePrice	0.001*	-0.021***
	(0.060)	(0.026)
log_population	0.032***	0.256**
	(0.046)	(0.050)
Coca Production	0.002	-0.001
	(0.006)	(0.005)
Region Fixed Effects	No	Yes
Year Fixed Effects	No	No
Department-Specific trends	No	No
Observations	13,271	13,271

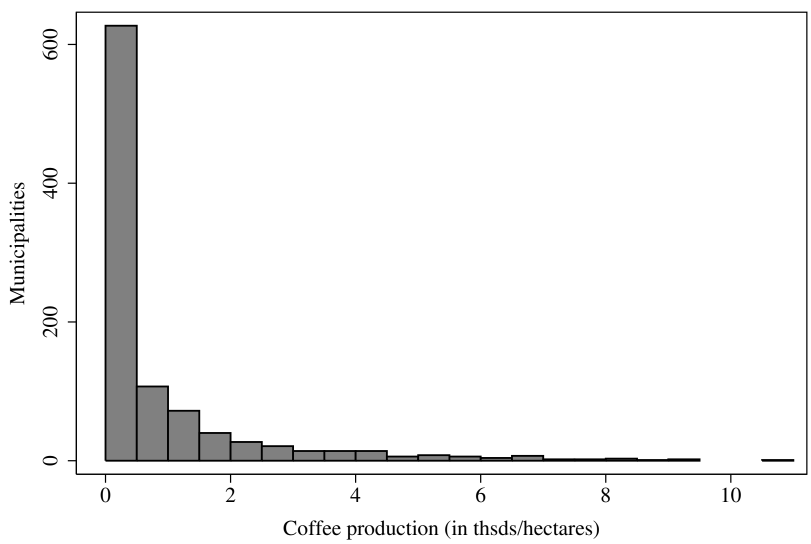
Source: Research results.
Notes: The dependent variable is the natural logarithm of the years of schooling or mortality data in municipality m, department d and, year t. *** p<0.01, ** p<0.05, * p<0.1

Figure 1: Geography of Coffee Cultivation in 1997.



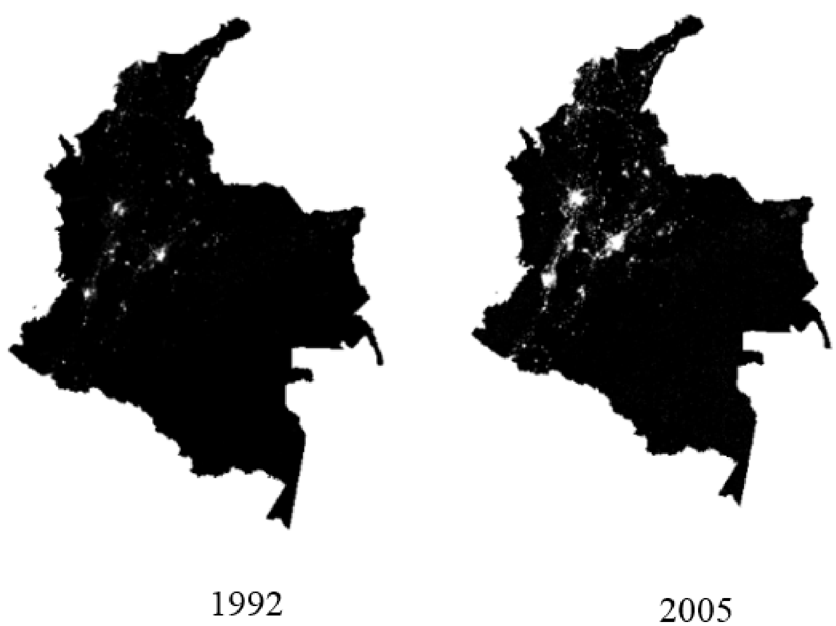
Note: Author's calculation based on data from Dube and Vargas (2013).

Figure 2: Geography of Coffee Cultivation in 1997.



Note: Author?s calculation based on data from Dube and Vargas (2013).

Figure 3: Changes in Night-Lights intensity over Colombia. (1992-2005)



Note: Author's calculation based on data from Dube and Vargas (2013).

Appendix

Figure A1: Annual Average of Internal Coffee Prices (1990-2005)

Notes. Author's elaboration.

Figure A2: Relationship Lights and GDP at the National level (1990-2005)

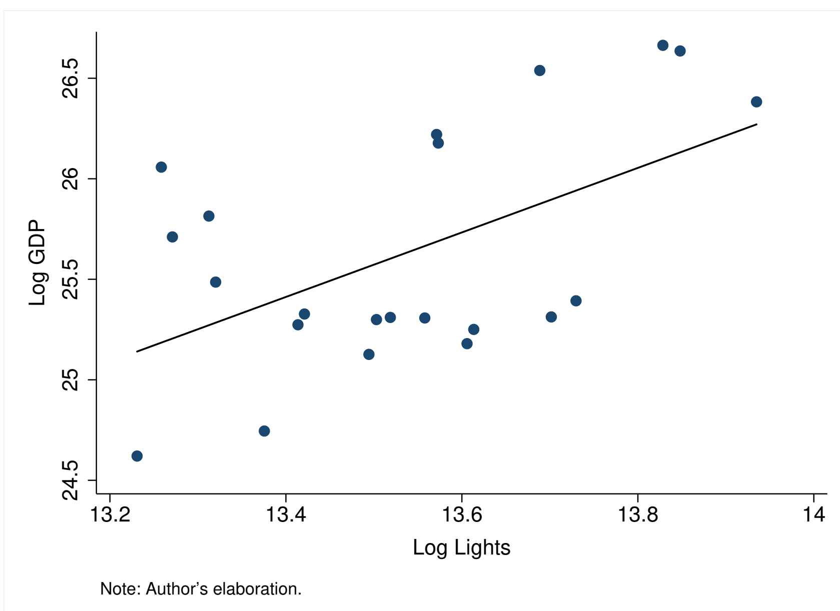
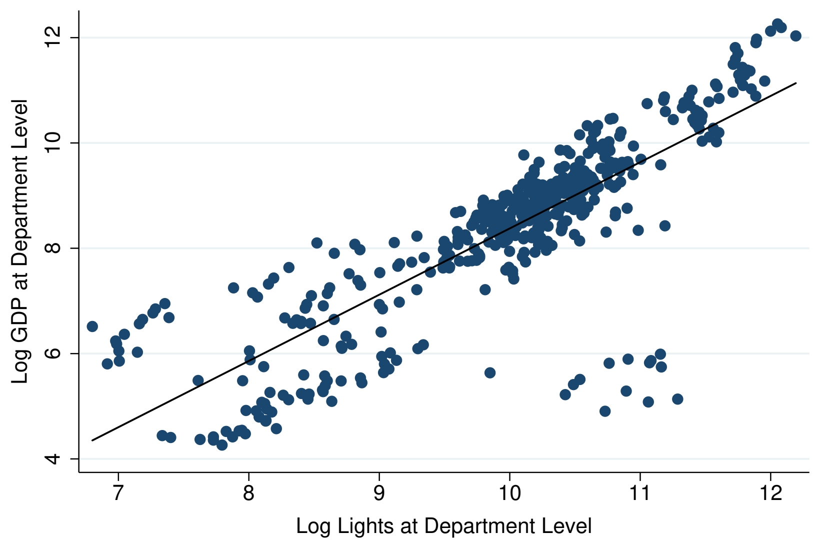


Figure A3: Relationship Lights and GDP at the Deparment level (1990-2005)



Note: Author's elaboration.