Peace and Misallocation: The case of manufacturing firms in Colombia

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Abstract:

This paper studies the effects of the peace process on the misallocation of firms located in the regions most affected by the armed conflict in Colombia. For this purpose, we used data from the Annual Manufacturing Survey (EAM) for the period 2000-2021 and applied the model proposed by Hsieh and Klenow (2009) to construct indicators of output and capital distortions, as well as total factor productivity (TFP). To assess the impact of the start of the peace negotiations, a difference-in-difference model was estimated. The results showed that plants located in the departments most affected by the war presented a decrease in output distortion (with a consequent increase in capital distortion) and an increase in total factor productivity compared to those firms located in the less affected departments.

Keywords: Misallocation, output distortion, capital distortion, TFP, peace process

JEL classification: C52, D24, D74, O47

Resumo:

Este artigo estuda os efeitos do processo de paz na má alocação de empresas localizadas nas regiões mais afetadas pelo conflito armado na Colômbia. Para isso, usamos dados da Pesquisa Anual de Manufatura (EAM) para o período de 2000-2021 e aplicamos o modelo proposto por Hsieh e Klenow (2009) para construir indicadores de distorções de produção e capital, bem como de produtividade total dos fatores (PTF). Para avaliar o impacto do início das negociações de paz, foi estimado um modelo de diferença em diferença. Os resultados mostraram que as plantas localizadas nos departamentos mais afetados pela guerra apresentaram uma diminuição na distorção da produção (com um consequente aumento na distorção do capital) e um aumento na produtividade total dos fatores em comparação com as empresas localizadas nos departamentos menos afetados.

Palavras-chave: Má alocação, distorção da produção, distorção do capital, PTF, processo de paz

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Introduction

Wars are terrible events that affect all sectors of society and cause damage that goes beyond physical capital and the economy. Wars exacerbate poverty, increase inequality, destroy human capital, create insecurity, undermine entrepreneurship, and reduce both economic growth and development. For example, Collier (1999) estimates that civil wars reduce annual GDP growth by 2.2 percent. Farzanegan (2022) finds that the war with Iraq reduced the real per capita income of the average Iranian by 40%. Novta and Pugacheva (2021) estimate that private consumption falls by 25% and per capita income by 28% ten years after a conflict. Devadas et al. (2021) show that the conflict in Syria led to negative GDP growth of -12% on average during 2011-2018.

Colombia has suffered an internal conflict with the Revolutionary Armed Forces of Colombia-People's Army (FARC) since the mid-1960s. For more than 60 years the country has been suffering the adverse effects of the war. During this period, there have been many human rights violations by the FARC and other guerrilla groups in Colombia. According to figures from the Special Jurisdiction for Peace (JEP), the FARC has committed 96,952 homicides, 29,410 forced disappearances, 20,223 kidnappings, and 12,038 recruitments of children and adolescents (JEP, 2023). To put an end to so many years of war and bloodshed, in 2012 the Colombian government began negotiations with the FARC, which culminated in a peace agreement signed in 2016.

In this context, this article investigates the effects of the peace process in Colombia on the misallocation of plants located in the departments most affected by the war with the FARC using a difference-in-differences model. For this purpose, the model proposed by Hsieh and Klenow (2009) is used, capital and output distortions are calculated, and total factor productivity is estimated. The data used correspond to those of Colombia's annual manufacturing survey (EAM) for the period 2000-2021.

The results suggest that after the beginning of the peace process negotiations, there was a decrease in the output distortion of the plants located in the departments most affected by the war compared to the group of plants located in the less affected departments. However, the distortion of capital increased in those same plants after the beginning of the peace process. This can be explained by the inverse relationship between the two indicators. When looking at the effect on physical productivity, it is observed that the plants located in the departments most affected by the war also increased their total factor productivity compared to the control group.

This paper is structured as follows: first, the background of the war in Colombia is presented together with the corresponding empirical evidence. Next, the methodology used is described in detail. Subsequently, the results obtained are presented and an analysis of their robustness is presented. Finally, the conclusions derived from this study are presented.

War in Colombia

The Colombian guerrillas were born as a result of violence and persecution by the Colombian state as a mechanism of social and political control, which sought to homogenize the population ideologically and politically. Thus, campaigns were carried out by the police and the army in towns and villages where hundreds of people were executed in order to annihilate and subdue political dissidents with ideologies different from conservative ones. The birth of the FARC originated in the departments of Tolima, Huila, and Cauca, where the peasant population organized to confront and resist the violence suffered by the Colombian government. For its part, the ELN is nourished mainly by peasants and academics very close to the Cuban revolution (Medina, 2010).

Thus, both guerrillas were born in the mid-1960s and over time have distorted their political ideals, seriously affecting communities throughout the country with acts of terrorism, assassinations, and kidnappings. With more than 60 years of conflict, both groups have financed and benefited from various forms of illegal activities located in Colombian territory (drug trafficking, kidnapping, extortion). According to the historical memory group, in early 2000, the FARC had 28,000 fighters in arms and were present in 60% of Colombian municipalities where most of its members came from the most impoverished rural communities.

Various sources mentioned by Gluecker et al. (2022) indicate that more than 9 million people have been victims of political violence, more than 6 million Colombians were internally displaced and at least 220,000 people were killed in the conflict. Within the armed conflict, multiple actors (in addition to the guerrillas) emerged. To protect their property and personal integrity, the United Self-Defense Forces of Colombia (AUC), a paramilitary group that became the third force in the conflict, appeared in the mid-1990s.

From the beginning of his term in office, President Juan Manuel Santos contemplated the possibility of reaching a peace agreement with the FARC. Through the enactment of "Ley de Víctimas y Restitución de Tierras" in (2011), Santos officially expressed his intention to resume talks with the guerrillas. This led to a series of secret communications through intermediaries between the insurgency and the government. These liaisons allowed face-to-face meetings to be established in Cuba, where confidential negotiations were held from 2011 until some months of 2012 (Espectador, 2020; Semana, 2012). Finally, these meetings were formalized on September 4, 2012, marking the beginning of the official peace negotiations.

During the following years, negotiations continued while both factions continued to conduct military operations. On December 17, 2014, the FARC unilaterally declared an indefinite ceasefire. Subsequently, on June 23, 2016, both parties signed a definitive ceasefire, culminating in the signing of the peace agreement on September 26, 2016, ending four years of negotiations. However, the agreement was submitted to a popular referendum on October 2, 2016, in which the non-implementation of the agreement won. Consequently, some points of the agreement had to be modified and renegotiated, reaching a final agreement on November 24, 2016.

Empirical evidence

The literature on the effects of war conflicts on business productivity is extensive. Freire and Resende (2020) find negative shocks to the conditional volatility of industrial output growth in the textile, machinery, and metals sectors because of the Civil War in the United States. . Khan (2015) explains that during the U.S. Civil War, there was a significant temporal misallocation of resources, reducing geographic mobility and creating incentives for individuals with high opportunity costs to engage in the market for military technologies, while reducing financial returns to investors. On the other hand, Field (2008) estimates that during the period from 1941 to 1948, the private non-agricultural economy experienced slower total factor productivity (TFP) growth compared to periods before or after World War II.

In the case of Colombia, there is a series of papers that explore the effects of the peace process on firm productivity. For example, Bernal et al. (2024) found that new firms were created differentially in FARC zones after the beginning of the ceasefire. New firms are created in several sectors, which also imply net employment gains. However, they explain that the effect is ephemeral since after the referendum and the political victory of the No vote, business creation fell again. For his part, Jola-Sanchez (2022) found that war increases TFP in service firms, such as public administration and defense, by up to 12.68%, while it decreases TFP in manufacturing and other non-service firms by up to 3.64% one year after a violent episode occurs.

Other papers also explore the effects of the peace agreement on different variables in the Colombian economy. De Roux and Martínez (2022) showed that business lending increased in municipalities with a historical FARC presence after the peace agreement, due to more credit applications with no change in supply. However, investment increased only in municipalities close to markets and not before the end of the peace agreement, despite the decrease in violence. Nino et al. (2023) found that in areas where the armed group was initially present, the end of the conflict led to a more than two-fold increase in agricultural investment, as farmers shifted production from annual crops to perennial crops.

In this regard, Prem et al. (2023) show how the permanent ceasefire declared by the FARC insurgency during peace negotiations with the Colombian government caused a differential improvement in several educational outcomes in areas affected by FARC violence prior to the ceasefire. Guerra-Cújar et al. (2024) found that the end of the internal conflict increased fertility by 2.6% in areas exposed to violence. The effect is present in all productive ages and is greater in municipalities with higher levels of exposure to violence at baseline.

Methodology

This section presents the data used together with the theoretical model used to estimate the inefficient allocation of resources, in addition to the difference-in-differences model implemented as an empirical strategy.

Data

This research used the Annual Manufacturing Survey of Colombia (EAM) implemented by the National Statistics Department (DANE) for the period between 2000 and 2021. The EAM comprises all establishments in the country that, according to the International Standard Industrial Classification (ISIC) adapted for Colombia, are identified as industrial. This survey generates key indicators for the national accounts, making it possible to measure the evolution and behavior of the industrial sector through variables such as employed personnel, gross production, employment, remunerations, intermediate consumption, value-added, electricity consumption, and investment in fixed assets, which are calculated annually.

For the construction and homogenization of the sectors, we used (ISIC) Revision 2 in 2000, (ISIC) Revision 3 from 2001 to 2011, and (ISIC) Revision 4 from 2012 to 2021 at the 4-digit level, which allows us to identify specific homogeneous manufacturing activities according to their production. The survey does not cover all establishments, but only those with ten or more people employed or with a minimum production value established annually, adjusted according to the Producer Price Index (PPI). The results obtained provide information on the structure and characteristics of the sector, allowing us to determine the composition and distribution of the industry at the national, regional, and departmental levels. We performed the analysis with an unbalanced panel of 158,750 plant-year observations for the period studied.

Deriving Misallocation and TFP

To illustrate the effect of resource misallocation on aggregate productivity, we use the model proposed by Hsieh and Klenow (2009). This model is based on a standard framework of monopolistic competition with heterogeneous firms, where firms vary in their efficiency levels and face distortions in both capital and output. Initially, it is assumed that there is a single final good Y produced by a representative firm in a perfectly competitive final output market. In turn, industrial production is constituted as a CES aggregate of *Ns* differentiated products:

$$Y_s = \left(\sum_{i=1}^{N_s} Y_{si}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{1}$$

Y_s represents the output of industry s, while Y_{si} represents the output of a plant i in industry s. The elasticity of substitution between plants used will be de $\sigma = 3$ and we set the rental price of capital $R=10\%$ in agreement with works such as Broda et al. (2006), Camacho et al. (2024), and Camacho and Conover (2010). In turn, the production function of each firm i in sector s is Cobb-Douglas with constant returns to scale:

$$Y_{si} = A_{si} K_{si}^{\alpha_s} L_{si}^{1-\alpha_s} \tag{2}$$

It is assumed that the percentages of capital and labor may vary between industries but not between firms in the same industry. For the construction of the elasticity of output with respect to capital in each industry α_s is defined as the summation of the output elasticities of each plant, α_{si} defined in equation 3 respectively:

$$\alpha_{si} = \left(1 - \frac{wL_{si}}{VA_{si}}\right)\frac{VA_{si}}{\sum_{j\in s}VA_{sj}} \quad \text{con } \alpha_s = \sum_{i\in s}\alpha_{si} \tag{3}$$

wL_{si} represents wages and is used as labor input, while VA_{si} represents the value added generated by plant i in industry s. We call dk_{si} the capital distortion, and dy_{si} the output distortion which affects both the marginal product of labor and the marginal product of capital. Firm-specific distortions and productivity were derived using the following equations from Hsieh and Klenow (2009):

$$dk_{si} = \frac{\alpha_s}{1-\alpha_s}\frac{wL_{si}}{RK_{si}} - 1 \tag{4}$$

$$dY_{si} = 1 - \frac{\sigma}{\sigma-1}\frac{wL_{si}}{(1-\alpha_s)VA_{si}} \tag{5}$$

$$A_{si} = k_s\frac{VA_{si}^{\frac{\sigma}{\sigma-1}}}{K_{si}^{\alpha_s}L_{si}^{1-\alpha_s}} \tag{6}$$

In our data the capital stock K_{si} is determined by the firms' buildings, structures, machinery and equipment. Since k_s is not observed in the data we normalize assuming $k_s = 1$, this normalization does not affect the results. On the other hand, Equation 4 indicates that capital distortion exists when the ratio of labor compensation to capital stock is high with respect to output elasticities. Equation 5 indicates that an output distortion is deduced when the labor share is low relative to the income-adjusted output elasticity.

Hsieh and Klenow (2009) explain that restrictions in access to credit can generate capital distortion and that aspects such as transportation costs or government penalties affect production distortion. They also point out that a high distortion of labor would imply a low distortion of capital. In this context, the marginal product of capital and labor are affected by these distortions in the following way:

$$MRPK_{si} = R\frac{1+dk_{si}}{1-dy_{si}} \tag{7}$$

$$MRPL_{si} = w \frac{1}{1 - dy_{si}} \tag{8}$$

With this information, it is possible to obtain an expression of aggregate TFP as a function of the misallocation of capital and labor. For this purpose, as Foster et al. (2008) explain, it is useful to distinguish between physical productivity ($TFPQ_{si}$) and income productivity ($TFPR_{si}$):

$$TFPQ_{si} \equiv A_{si} = \frac{Y_{si}}{K_{si}^{\alpha_s} w L_{si}^{1-\alpha_s}} \tag{9}$$

$$TFPR_{si} \equiv P_{si} A_{si} = \frac{P_{si} Y_{si}}{K_{si}^{\alpha_s} w L_{si}^{1-\alpha_s}} \tag{10}$$

Using equation 7 and 8, the $TFPR_{si}$ proportional to the geometric mean of the marginal products of capital and plant labor. Thus equation 10 can be rewritten as:

$$TFPR_{si} = \frac{\sigma}{\sigma-1} \left(\frac{MRPK_{si}}{\alpha_s} \right)^{\alpha_s} \left(\frac{MRPL_{si}}{w(1-\alpha_s)} \right)^{1-\alpha_s} = \frac{\sigma}{\sigma-1} \left(\frac{R}{\alpha_s} \right)^{\alpha_s} \left(\frac{1}{(1-\alpha_s)} \right)^{1-\alpha_s} \frac{1+dk_{si}}{1-dy_{si}} \tag{11}$$

Empirical strategy

A difference-in-differences model was implemented to take advantage of the timing of the start of the peace treaty negotiations in 2012, as well as the spatial distribution of the departments most exposed to FARC violence before and after the treaty. This type of model allows us to assess the causal impact of a treatment, intervention, or event on a treatment group compared to a control group over time (Ciani and Fisher, 2019; Cunningham, 2021). Advantages of the difference-in-differences model include its ability to control for time-constant unobserved factors and its ability to handle endogeneity issues, as it compares changes within the same groups over time. In addition, it can provide more robust estimates when random assignment is not possible and is less prone to biases caused by common temporal factors.

The main hypothesis of the model is that, in the absence of the armed conflict, there would be decreases in the distortions of either capital or production and therefore the TFP of firms in the departments most exposed to violence would tend to increase similarly to the TFP of the less exposed departments. Formally, the subscript s will be used to denote the industry, i to denote the plant, d to denote the departments where the plants are located and t to denote the year. In this way, the following regression models were estimated:

$$dY_{sidt} = \alpha_{pd} + \theta_d + \varphi_s + \delta(Cease_t \times Farc_{di}) + \varepsilon_{idt} \tag{12}$$

$$dK_{sidt} = \alpha_{pd} + \theta_d + \varphi_s + \delta(Cease_t \times Farc_{di}) + \varepsilon_{idt} \qquad (13)$$

$$TFPQ_{sidt} = \alpha_{pd} + \theta_d + \varphi_s + \delta(Cease_t \times Farc_{di}) + \varepsilon_{idt} \qquad (14)$$

Where the dependent variables are output distortion dY_{sidt}, capital distortion dK_{sidt} and total factor productivity $TFPQ_{sidt}$ that were previously estimated. α_{pd} are plant level fixed effects, θ_d are departmental fixed effects and φ_s are industry fixed effects. For its part, δ is the coefficient of interest in this research as it captures the differential effect on the variables studied after the start of the peace negotiations in Colombia.

The variable $Farc_{di}$ takes as treated the departments with more exposure to FARC violence before the beginning of the negotiations for the signing of the peace treaty. To determine these departments, data collected by the joint project of the Truth Clarification Commission and the Special Jurisdiction for Peace (JEP), together with the Human Rights Violations Data Analysis Group (HRDAG) was used. This Colombian government initiative provided data related to five human rights violations such as homicides, forced disappearance, kidnapping, recruitment and forced displacement (JEP-HRDAG., 2022).

Considering the above, the departments that appeared at least twice in the top 5 victims of the five human rights violations were chosen as the ones to be treated. Thus, the departments selected in this research are Antioquia, Bolivar, Nariño, Valle del Cauca, Cauca, Cesar, Norte de Santander and Meta. Finally, the variable $Cease_t$ takes as a value of 1 the period from the beginning of the negotiations in 2012 onwards and zero the period prior to the peace negotiations.

Results

Descriptive statistics

Table 1 shows the evaluation of the number of firms by sector. On average, the largest proportion of firms is in the food sector, representing approximately 19% of the total. This is followed by the textile sector and the chemicals and plastics sector, with approximately 15.45% and 15.18%, respectively. In contrast, the sectors with the lowest proportion of establishments are petroleum refineries, medical supplements, and vehicles, with proportions of approximately 0.77%, 1.77%, and 3.42% respectively.

On the other hand, Table 2 shows the mean and standard deviation of capital and labor provisions, marginal product of capital and labor, and finally physical and income productivity, all at the firm level. On average, capital distortions remain around 2.94 with a standard deviation of 1.38 log units. Output distortions range between 0.27 and 0.67 log units. The marginal products of capital and labor are consistently negative but both show decreases in their averages. The $TFPQ_{si}$ remains relatively stable at around 7.50 log units, while the $TFPR_{si}$ is at 0.31 log units and shows decreasing values when comparing the initial and final years.

Table 1. Firms by sector

Año	Wood and paper	Machinery and equipment	Metals and nonmetals	Furniture	Foodstuffs	Chemicals, rubber and plastics	Oil refining	Textile	Vehicles	Edition and printing	Medical supplies	Other manufacturing industries	Total
2001	311	459	799	759	1,373	905	22	1,113	162	298	33		6,234
2002	303	424	786	738	1,349	932	19	1,041	160	306	36		6,094
2003	342	454	819	757	1,353	1,001	18	1,113	168	320	37		6,382
2004	316	449	820	757	1,312	1,028	18	1,075	177	319	35		6,306
2005	329	481	851	762	1,338	1,085	18	1,086	187	338	38		6,513
2006	313	467	894	777	1,320	1,096	18	1,048	166	359	40		6,498
2007	238	468	879	759	1,302	1,071	21	1,053	177	427	41		6,436
2008	270	532	974	806	1,375	1,209	21	1,097	197	495	41		7,017
2009	297	614	1,145	873	1,512	1,356	30	1,342	217	595	59		8,040
2010	329	691	1,252	958	1,609	1,442	46	1,417	218	633	66		8,661
2011	309	669	1,252	933	1,547	1,426	85	1,397	214	611	68		8,511
2012	298	624	1,251	395	1,520	1,176	71	1,300	198	435	195	811	8,274
2013	291	657	1,261	411	1,574	1,233	90	1,313	206	478	203	616	8,333
2014	304	628	1,270	362	1,554	1,203	93	1,257	200	480	197	621	8,169
2015	296	617	1,214	341	1,516	1,167	85	1,237	191	458	195	679	7,996
2016	298	578	1,202	322	1,508	1,168	101	1,250	194	397	191	414	7,623
2017	292	526	1,191	304	1,478	1,156	98	1,202	189	371	182	426	7,415
2018	271	495	1,121	299	1,409	1,116	93	1,111	169	353	175	551	7,163
2019	254	474	1,061	283	1,393	1,108	89	1,072	160	338	168	536	6,936
2020	245	463	1,021	265	1,368	1,086	88	986	153	319	167	521	6,682
2021	248	434	968	251	1,341	1,068	90	955	148	306	169	538	6,516
Total	6,154	11,204	22,031	12,112	30,051	24,032	1,214	24,465	3,851	8,636	2,336	5,713	151,799

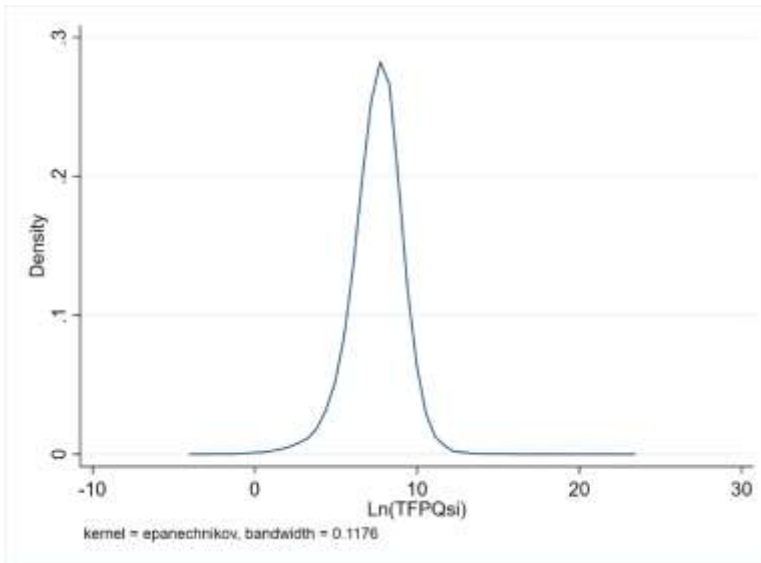. Source: Prepared by the authors based on the EAM 2001-2021.

Table 2. Distortions, marginal products and TFP statistics

Year	Ln(dK_{si})		Ln(dY_{si})		Ln($MRPK_{si}$)		Ln($MRPL_{si}$)		Ln($TFPQ_{si}$)		Ln($TFPR_{si}$)	
	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd
2000	2.94	1.38	0.43	0.34	-11.18	2.27	-8.24	1.78	7.33	1.54	0.26	1.12
2001	2.97	1.36	0.55	0.18	-10.27	2.23	-7.31	1.63	7.42	1.48	0.28	1.08
2002	2.92	1.37	0.47	0.12	-10.27	2.23	-7.36	1.64	7.44	1.48	0.27	1.08
2003	2.89	1.46	0.41	0.10	-10.26	2.29	-7.38	1.63	7.55	1.50	0.34	1.14
2004	2.88	1.41	0.35	0.10	-10.30	2.22	-7.43	1.62	7.62	1.51	0.38	1.10
2005	2.89	1.43	0.33	0.11	-10.43	2.24	-7.54	1.62	7.55	1.52	0.36	1.11
2006	2.86	1.45	0.27	0.16	-10.41	2.25	-7.55	1.63	7.65	1.55	0.38	1.14
2007	2.94	1.47	0.27	0.16	-10.50	2.29	-7.56	1.65	7.66	1.62	0.40	1.19
2008	2.96	1.39	0.30	0.11	-10.57	2.23	-7.61	1.63	7.66	1.56	0.43	1.14
2009	3.01	1.41	0.36	0.10	-10.69	2.20	-7.69	1.60	7.54	1.61	0.41	1.19
2010	3.05	1.45	0.38	0.13	-10.77	2.23	-7.73	1.59	7.50	1.60	0.41	1.21
2011	3.05	1.45	0.35	0.12	-10.79	2.22	-7.74	1.61	7.55	1.63	0.43	1.21
2012	3.02	1.45	0.47	0.30	-10.47	2.18	-7.45	1.67	7.58	1.58	0.42	1.17

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2013	2.97	1.43	0.49	0.29	-10.42	2.20	-7.46	1.69	7.45	1.68	0.31	1.21
2014	3.00	1.44	0.50	0.29	-10.41	2.20	-7.42	1.69	7.45	1.71	0.30	1.23
2015	3.00	1.45	0.46	0.29	-10.43	2.22	-7.43	1.69	7.47	1.75	0.31	1.24
2016	3.00	1.44	0.45	0.31	-10.33	2.20	-7.35	1.70	7.54	1.73	0.31	1.24
2017	2.99	1.44	0.52	0.30	-10.22	2.21	-7.24	1.68	7.48	1.69	0.24	1.22
2018	2.99	1.47	0.50	0.31	-10.18	2.23	-7.20	1.65	7.49	1.74	0.23	1.25
2019	2.95	1.48	0.51	0.28	-10.11	2.24	-7.18	1.67	7.49	1.74	0.20	1.25
2020	2.91	1.42	0.67	0.28	- 9.98	2.24	-7.09	1.74	7.25	1.86	0.02	1.27
2021	2.98	1.47	0.52	0.26	-10.17	2.28	-7.20	1.74	7.56	1.84	0.22	1.29

Source: Prepared by the authors based on the EAM 2000-2021.

Figure 1. Density graph of $TFPQ_{si}$

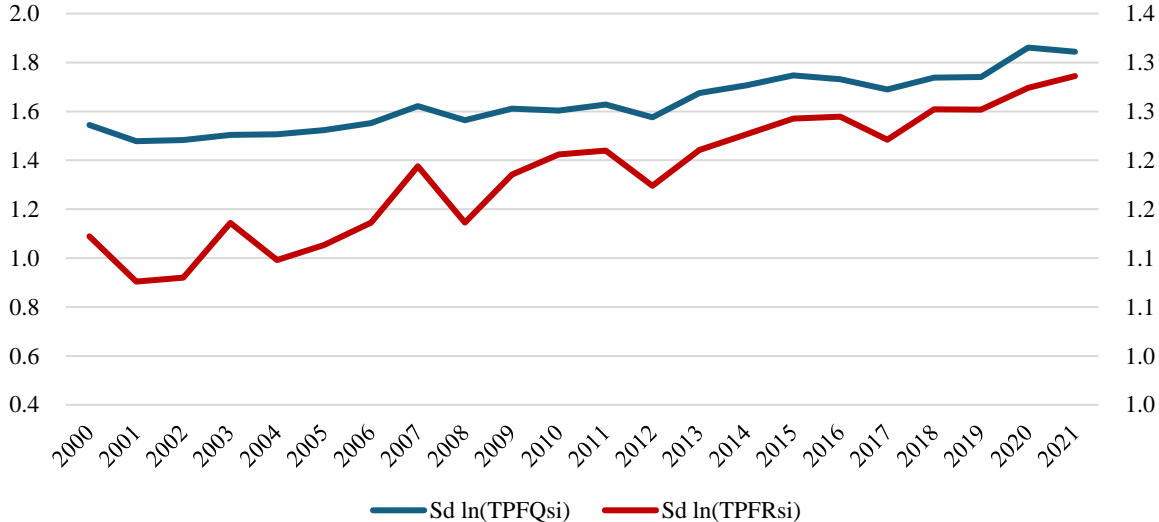Source: Prepared by the authors based on the EAM 2000-2021.

Figure 2. Density graph of $TFPR_{si}$
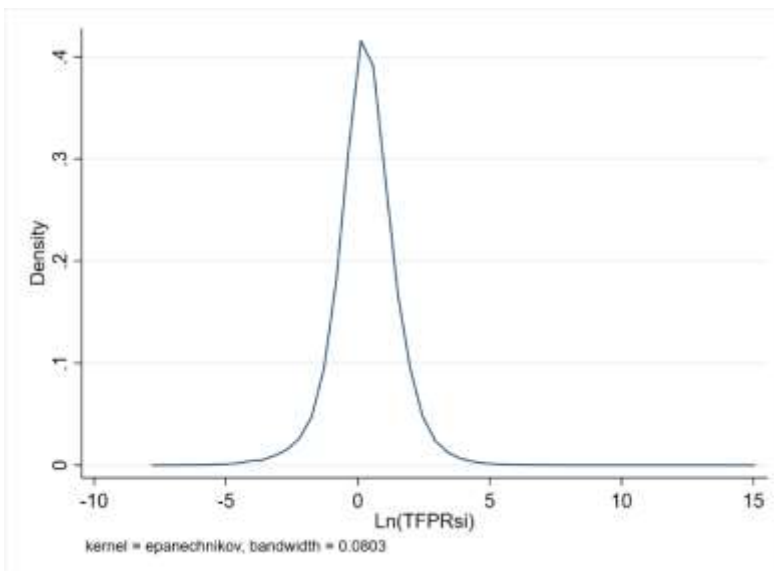
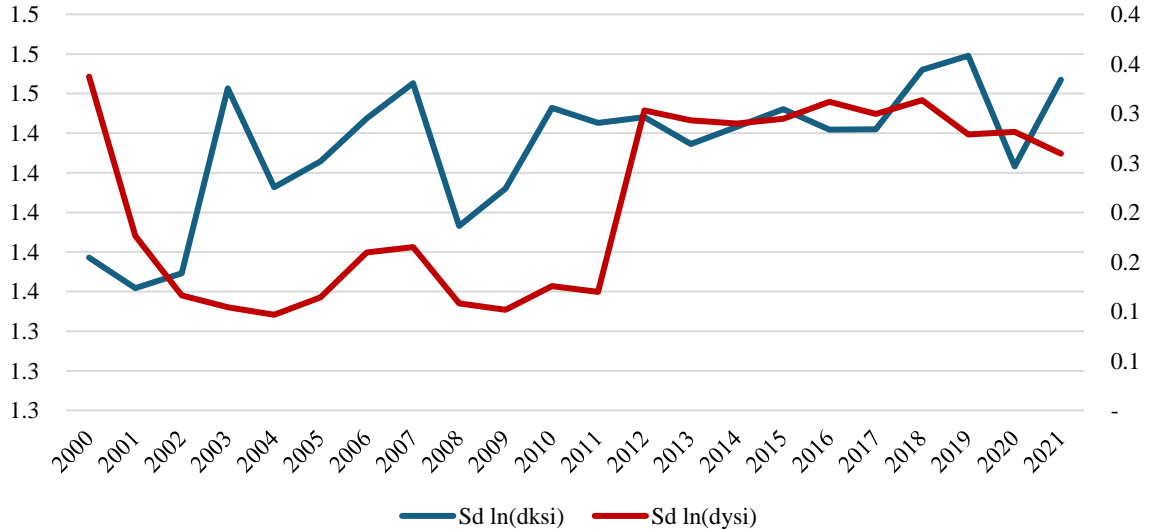Source: Prepared by the authors based on the EAM 2000-2021.

Both Figure 1 and Figure 2 show that most of the firms in the sample have similar levels of physical productivity concentrated in the central region, although they present values that may suggest a skew to the right of the distribution.

Figure 3. Dispersion of $\ln(TFPQ_{si})$ and $\ln(TFPR_{si})$

Figure 4. Dispersion of $\ln(dK_{si})$ and $\ln(dY_{si})$

Figure 3 shows the dispersion of physical productivity and income productivity. It is observed that both productivities follow a very similar pattern in their dispersion. In this sense, income productivity shows more abrupt changes in its dispersion. Additionally, although the dispersion of physical productivity in the last two years shows a more stable and downward trend, the dispersion of income productivity is increasing.

Similarly, Figure 4 shows the behavior of the dispersion in the capital wedge and the output wedge. It can be observed that the dispersion of the capital wedge is much more variable than that of the output wedge. However, the output wedge shows an abrupt change in dispersion in 2011 and then stabilizes in subsequent years, with a downward trend in recent years.

Figure 5. Average product distortion at plants located in treated and control departments

mean ln(ysi) treat   mean ln(ysi) control
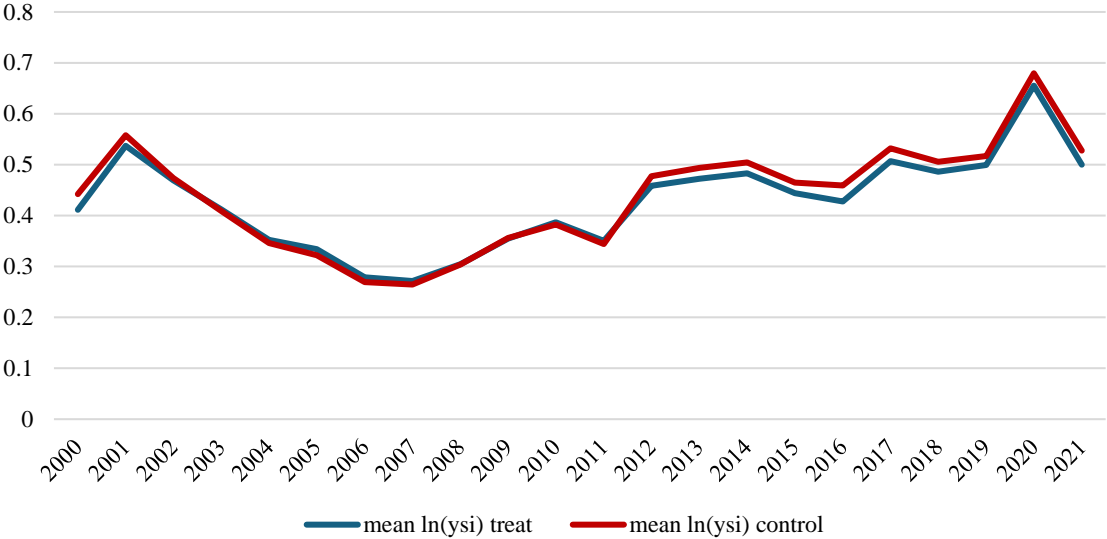
Figure 6. Average capital distortion in plants located in treated and control departments

mean ln(dki) treat   mean ln(dki) control
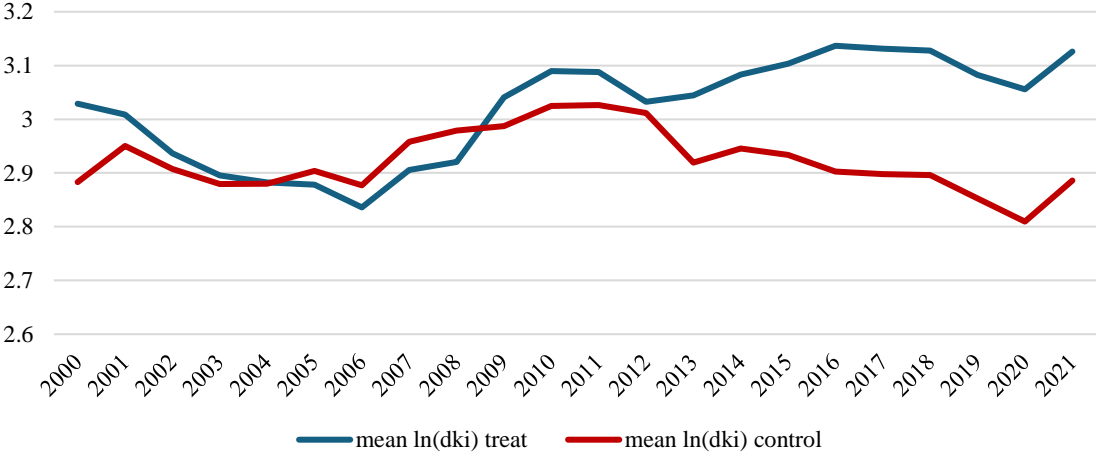
En la Figura 5, se observa la evolución de la distorsión promedio del producto. Se aprecia que, desde 2002 hasta 2011, las líneas se superponen. Sin embargo, a partir de 2012 se evidencia un ligero cambio: las plantas ubicadas en los departamentos tratados (línea azul) presentan una disminución en la distorsión del producto en comparación con las plantas ubicadas en los departamentos de control. De forma análoga, en la Figura 6 se observa que,

desde 2012, la distorsión del capital en las plantas ubicadas en los departamentos con mayor presencia de las FARC (tratados) aumenta, mientras que en el resto de los departamentos disminuye.

Estimation of Difference-in-Difference Models

Table 3. Effects of the peace process on the product distortion

$Ln(dY_{si})$	(1)	(2)	(3)	(4)	(5)
Farc	0.0446***	0.0446	0.0446	0.141***	0.0857***
	(0.0147)	(0.0278)	(0.0292)	(0.00666)	(0.00733)
Cease	0.143***	0.143***	0.143***	0.141***	0.143***
	(0.00150)	(0.00467)	(0.00439)	(0.00457)	(0.00490)
Farc*Cease	-0.0254***	-0.0254***	-0.0254***	-0.0241***	-0.0245***
	(0.00238)	(0.00671)	(0.00665)	(0.00666)	(0.00675)
Constant	0.353***	0.353***	0.353***	0.268***	0.219***
	(0.00593)	(0.0113)	(0.0117)	(0.0232)	(0.0289)
Observations	158,352	158,352	158,352	158,352	158,352
R-squared	0.084	0.084	0.084	0.084	0.138
Number of id	14,426	14,426	14,426	14,426	14,426

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. The variable Farc represents the departments treated, taking the value of 1 if the department suffered greater violations in the ranking of human rights violated by the war in Colombia. The variable "Cease" refers to the beginning of the peace process negotiations in 2012. Column 1 presents the estimates using plant fixed effects. Column 2 shows White's robust variance correction, maintaining the plant fixed effects. Column 3 repeats the estimates from column 1 using bootstrap with 1000 replications. In column 4, department fixed effects are added to the estimates in column 2, and in column 5, plant fixed effects are added to the estimates in column 4. Source: Prepared by the authors based on the EAM 2000-2021.

Table 3 presents the estimates of the difference-in-differences model to evaluate the effects of the peace negotiations on the dispersion of output in the departments most affected by the war. The results indicate that, after the start of negotiations with the FARC, there was a decrease in the output distortion of manufacturing establishments located in these departments compared to those without FARC presence. Column 5 shows the estimates with plant, department, and sector fixed effects. The results reveal a decrease of 2.45 percentage points in the output distortion of firms located in the departments most affected by the armed conflict. All estimates are statistically significant at 99% confidence.

Figure 7 presents the estimated effect of the peace process on the distortion of output for the period 2003-2021. Since 2012 there has been a decrease in the distortion of the product in the departments most affected by the war, which becomes more accentuated in 2016 with the signing of the peace treaty and is subsequently maintained over time.

This result can be explained by several factors. Output distortions arise when the labor share is low compared to what is expected based on the labor elasticity of industry output. In Colombia, plants located in the most affected departments faced greater difficulties in hiring workers due to the presence of the FARC, which discouraged many workers from moving to

these areas. As a result, companies had to offer higher wages, including a premium for operating in risk areas. In addition, these companies could face problems in their logistical chain, as "armed strikes" or difficulties generated by the FARC on the roads affected their transportation and distribution costs.

As for the onset of the effect in the base year, as mentioned above, since President Juan Manuel Santos took office in 2010, the Colombian government had been preparing the way to reach a peace agreement with the FARC. Several media outlets reported that these negotiations had been taking place long before the official date in September 2012. For this reason, the decrease in product distortions has been evident since 2012.

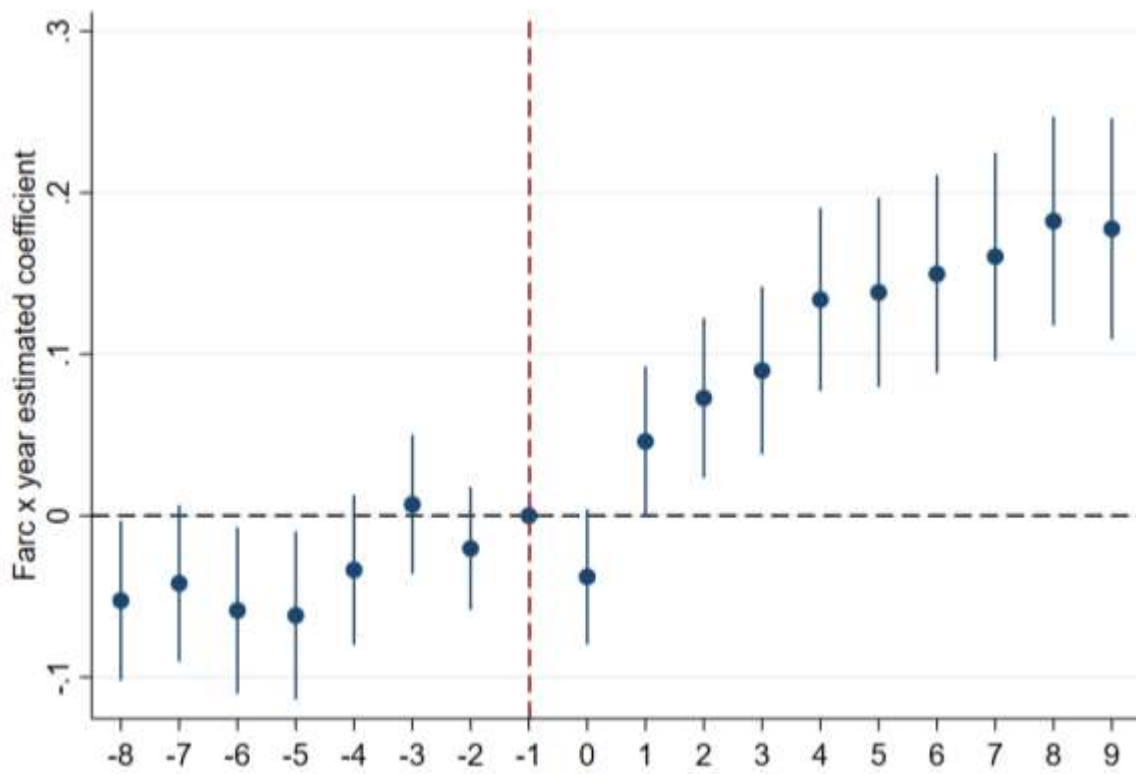Figure 7. Estimated effect of peace process on output distortion
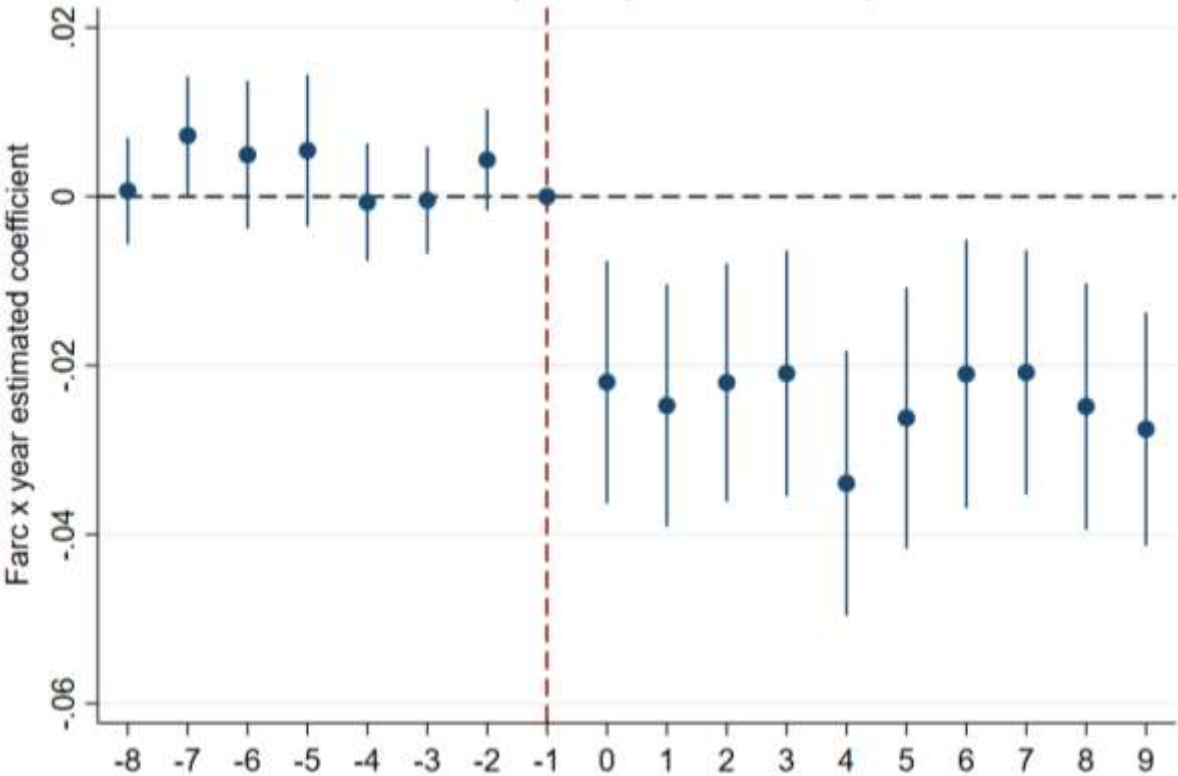
Table 4 shows the effects of the peace process negotiations on the capital distortion of firms located in the departments most affected by the war. The results suggest that, on average, after the peace treaty negotiations, the departments most affected by the conflict experienced an increase in the distortion of capital compared to those less affected. Specifically, column 5 shows that, with the beginning of the peace process, there was an increase of 10.4 percentage points in the distortion of capital in the departments most affected by the war.

Table 4. Effects of the peace process on capital distortion

Ln(dK_{si})	(1)	(2)	(3)	(4)	(5)
Farc	-0.188***	-0.188	-0.188	-1.487***	-1.375***
	(0.0620)	(0.131)	(0.128)	(0.0214)	(0.0250)
Cease	-0.150***	-0.150***	-0.150***	-0.143***	-0.104***
	(0.00628)	(0.0132)	(0.0135)	(0.0132)	(0.0130)
Farc*Cease	0.118***	0.118***	0.118***	0.113***	0.104***
	(0.00996)	(0.0213)	(0.0211)	(0.0214)	(0.0210)
Constant	3.091***	3.091***	3.091***	4.366***	4.079***
	(0.0249)	(0.0525)	(0.0526)	(0.149)	(0.157)
Observations	157,071	157,071	157,071	157,071	157,071
R-squared	0.004	0.004	0.004	0.005	0.061
Number of id	14,377	14,377	14,377	14,377	14,377

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. The variable Farc represents the departments treated, taking the value of 1 if the department suffered greater violations in the ranking of human rights violated by the war in Colombia. The variable "Cease" refers to the beginning of the peace process negotiations in 2012. Column 1 presents the estimates using plant fixed effects. Column 2 shows White's robust variance correction, maintaining the plant fixed effects. Column 3 repeats the estimates from column 1 using bootstrap with 1000 replications. In column 4, department fixed effects are added to the estimates in column 2, and in column 5, plant fixed effects are added to the estimates in column 4. Source: Prepared by the authors based on the EAM 2000-2021.

Figure 8. Estimated effect of peace process on Capital distortion

Source: Prepared by the authors based on the EAM 2003-2021.

Figure 8 presents the estimated effect of the peace process on capital distortion for 2003-2021. It is observed that after 2012 the distortion of capital increased steadily in the departments most affected by violence. This result can be understood considering what Hsieh and Klenow (2009) pointed out, where the distortion of capital and labor are inversely related, i.e. a decrease in the distortion of the product (therefore in the distortion of labor) produces an increase in the distortion of capital.

Another possible explanation is the effect of increased entry of new firms which, being new, face more credit restrictions and therefore face more capital distortions. This is consistent with the findings of Bernal et al. (2024) who found that new firms were created differentially in FARC zones after the beginning of the ceasefire.

Table 5. Effects of the Peace Process on Physical Productivity

| $Ln(TFPQ_{si})$	(1)	(2)	(3)	(4)	(5)
Farc	-0.112	-0.112	-0.112	-1.097***	-1.219***
	(0.0824)	(0.158)	(0.155)	(0.0255)	(0.0316)
Cease	-0.308***	-0.308***	-0.308***	-0.302***	-0.305***
	(0.00834)	(0.0167)	(0.0158)	(0.0166)	(0.0167)
Farc*Cease	0.183***	0.183***	0.183***	0.178***	0.182***
	(0.0132)	(0.0255)	(0.0261)	(0.0255)	(0.0255)
Constant	7.666***	7.666***	7.666***	8.708***	8.734***
	(0.0332)	(0.0632)	(0.0637)	(0.184)	(0.189)
Observations	157,071	157,071	157,071	157,071	157,071
R-squared	0.010	0.010	0.010	0.011	0.013
Number of id	14,377	14,377	14,377	14,377	14,377

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. The variable Farc represents the departments treated, taking the value of 1 if the department suffered greater violations in the ranking of human rights violated by the war in Colombia. The variable "Cease" refers to the beginning of the peace process negotiations in 2012. Column 1 presents the estimates using plant fixed effects. Column 2 shows White's robust variance correction, maintaining the plant fixed effects. Column 3 repeats the estimates from column 1 using bootstrap with 1000 replications. In column 4, department fixed effects are added to the estimates in column 2, and in column 5, plant fixed effects are added to the estimates in column 4. Source: Prepared by the authors based on the EAM 2000-2021.

Table 5 presents the effects of the peace process negotiations on physical total factor productivity (TFPQ). The estimates suggest that after 2012, the total factor productivity of firms increased in the departments most affected by the war compared to those departments less affected. Column 5 shows that with the beginning of the peace negotiations, there was an increase of 18.2 percentage points in the $TFPQ_{si}$ of the plants located in the departments with the greatest FARC presence. All estimates are significant at a 99% confidence level.

Figure 9 presents the estimated effect of the peace process on total factor productivity for the period 2003-2021. It is observed that after 2012 there is an increase in the physical productivity of the plants located in the departments with greater FARC presence compared to those plants located in the departments less affected by the war. This result can be explained by the decrease in the misallocation of resources (represented by the distortion of

the product), which generates a more efficient use of inputs and in turn an increase in the TFP of these companies.

Figure 9. Estimated effect of peace process on Physical productivity
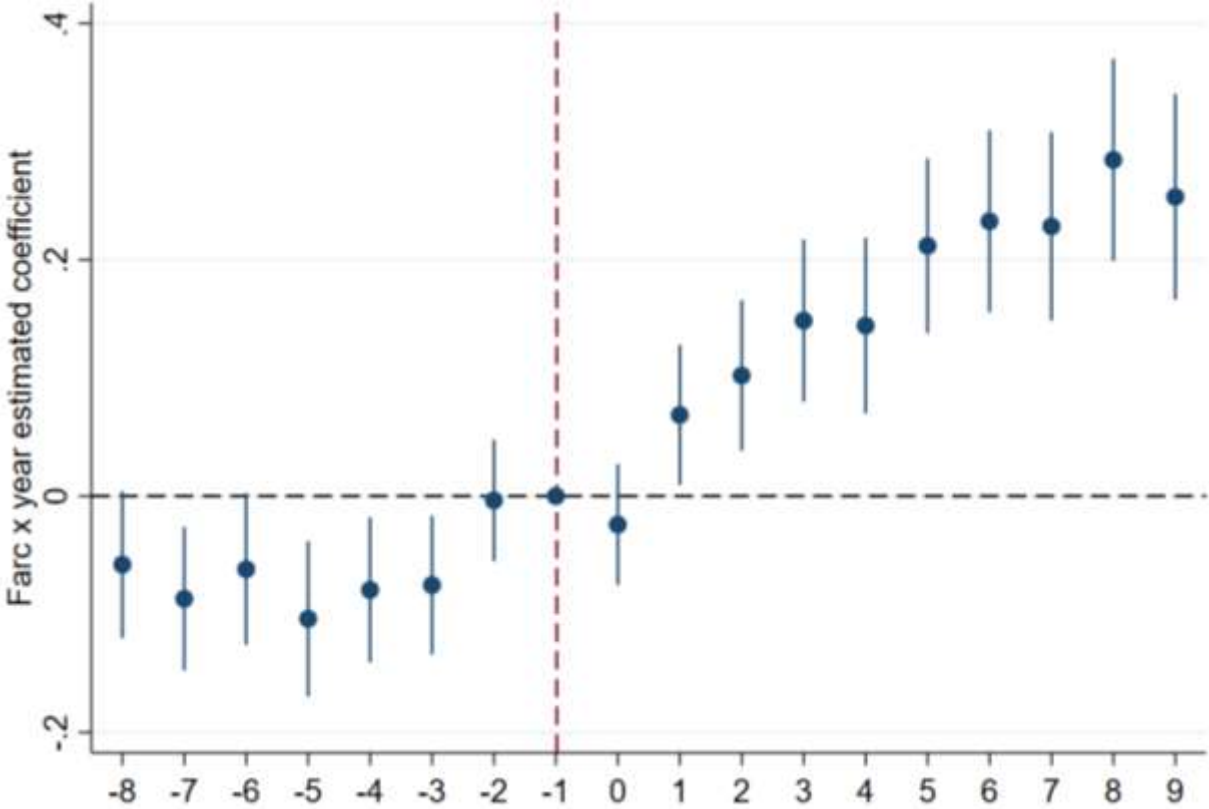
Robustness tests

In this section we modify some variables to observe the robustness of the estimated coefficients. In tables 6, 7 and 8, the same estimations of the difference-in-differences model were made but modifying the variable of the treaties (Farc). In this sense, the departments of Antioquia and Valle del Cauca, which together with Bogota account for approximately 44% of the country's GDP, were excluded. Therefore, to check if the results are being driven by this aspect, they are no longer taken as treated departments and the treatment variable now only has 5 departments.

Table 6 and 8 show that both the coefficient of capital distortion and the coefficient of physical productivity maintain their sign and statistical significance. This suggests that there is a difference effect on output distortion and total factor productivity. However, in Table 7 the results for capital distortion are only significant in estimators shown in column 1 and 5.

Table 6. Effects of the peace process on output distortion (excluding Antioquia and Valle del Cauca)

$Ln(dY_{si})$	(1)	(2)	(3)	(4)	(5)
Farc2	0.0334*	0.0334*	0.0334*	0.0167***	0.0113
	(0.0189)	(0.0191)	(0.0182)	(0.00633)	(0.00745)
Cease	0.136***	0.136***	0.136***	0.135***	0.136***
	(0.00120)	(0.00361)	(0.00371)	(0.00356)	(0.00383)
Farc2*Cease	-0.0587***	-0.0587***	-0.0587***	-0.0581***	-0.0530***
	(0.00482)	(0.00718)	(0.00680)	(0.00717)	(0.00803)
Constant	0.368***	0.368***	0.368***	0.399***	0.295***
	(0.00139)	(0.00207)	(0.00148)	(0.0229)	(0.0287)
Observations	158,352	158,352	158,352	158,352	158,352
R-squared	0.084	0.084	0.084	0.084	0.138
Number of id	14,426	14,426	14,426	14,426	14,426

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. The variable Farc2 represents the departments treated, taking the value of 1 if the department (except for the departments of Antioquia and Valle del Cauca) suffered greater violations in the ranking of human rights violated by the war in Colombia. The variable "Cease" refers to the beginning of the peace process negotiations in 2012. Column 1 presents the estimates using plant fixed effects. Column 2 shows White's robust variance correction, maintaining the plant fixed effects. Column 3 repeats the estimates from column 1 using bootstrap with 1000 replications. In column 4, department fixed effects are added to the estimates in column 2, and in column 5, plant fixed effects are added to the estimates in column 4. Source: Prepared by the authors based on the EAM 2000-2021.

Table 7. Effects of the peace process on the capital distortion (excluding Antioquia and Valle del Cauca)

$Ln(dK_{si})$	(1)	(2)	(3)	(4)	(5)
Farc2	-0.242***	-0.242	-0.242	-2.153***	-2.233***
	(0.0791)	(0.188)	(0.204)	(0.0478)	(0.0466)
Cease	-0.107***	-0.107***	-0.107***	-0.102***	-0.0681***
	(0.00503)	(0.0106)	(0.0111)	(0.0106)	(0.0105)
Farc2*Cease	0.0667***	0.0667	0.0667	0.0650	0.123**
	(0.0202)	(0.0489)	(0.0568)	(0.0489)	(0.0476)
Constant	3.031***	3.031***	3.031***	2.917***	2.742***
	(0.00585)	(0.0127)	(0.0168)	(0.148)	(0.156)
Observations	157,071	157,071	157,071	157,071	157,071
R-squared	0.003	0.003	0.003	0.004	0.060
Number of id	14,377	14,377	14,377	14,377	14,377

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. The variable Farc2 represents the departments treated, taking the value of 1 if the department (except for the departments of Antioquia and Valle del Cauca) suffered greater violations in the ranking of human rights violated by the war in Colombia. The variable "Cease" refers to the beginning of the peace process negotiations in 2012. Column 1 presents the estimates using plant fixed effects. Column 2 shows White's robust variance correction, maintaining the plant fixed effects. Column 3 repeats the estimates from column 1 using bootstrap with 1000 replications. In column 4, department fixed effects are added to the estimates in column 2, and in column 5, plant fixed effects are added to the estimates in column 4. Source: Prepared by the authors based on the EAM 2000-2021.

Table 8. Effects of the Peace Process on Physical Productivity (excluding Antioquia and Valle del Cauca)

$Ln(TFPQ_{si})$	(1)	(2)	(3)	(4)	(5)
Farc2	-0.112	-0.112	-0.112	-1.097***	-1.219***
	(0.0824)	(0.158)	(0.164)	(0.0255)	(0.0316)
Cease	-0.308***	-0.308***	-0.308***	-0.302***	-0.305***
	(0.00834)	(0.0167)	(0.0167)	(0.0166)	(0.0167)
Farc2*Cease	0.183***	0.183***	0.183***	0.178***	0.182***
	(0.0132)	(0.0255)	(0.0249)	(0.0255)	(0.0255)
Constant	7.666***	7.666***	7.666***	8.708***	8.734***
	(0.0332)	(0.0632)	(0.0657)	(0.184)	(0.189)
Observations	157,071	157,071	157,071	157,071	157,071
R-squared	0.010	0.010	0.010	0.011	0.013
Number of id	14,377	14,377	14,377	14,377	14,377

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. The variable Farc2 represents the departments treated, taking the value of 1 if the department (except for the departments of Antioquia and Valle del Cauca) suffered greater violations in the ranking of human rights violated by the war in Colombia. The variable "Cease" refers to the beginning of the peace process negotiations in 2012. Column 1 presents the estimates using plant fixed effects. Column 2 shows White's robust variance correction, maintaining the plant fixed effects. Column 3 repeats the estimates from column 1 using bootstrap with 1000 replications. In column 4, department fixed effects are added to the estimates in column 2, and in column 5, plant fixed effects are added to the estimates in column 4. Source: Prepared by the authors based on the EAM 2000-2021.

Table 9. Effects of the peace process on the output distortion (without the years 2020 and 2021)

$Ln(dY_{si})$	(1)	(2)	(3)	(4)	(5)
Farc	0.0414**	0.0414	0.0414	0.0687***	0.0153**
	(0.0161)	(0.0343)	(0.0349)	(0.00674)	(0.00741)
Cease	0.126***	0.126***	0.126***	0.125***	0.125***
	(0.00156)	(0.00472)	(0.00434)	(0.00464)	(0.00496)
Farc*Cease	-0.0256***	-0.0256***	-0.0256***	-0.0248***	-0.0249***
	(0.00249)	(0.00679)	(0.00675)	(0.00674)	(0.00685)
Constant	0.353***	0.353***	0.353***	0.324***	0.274***
	(0.00645)	(0.0138)	(0.0140)	(0.0190)	(0.0255)
Observations	145,154	145,154	145,154	145,154	145,154
R-squared	0.066	0.066	0.066	0.066	0.126
Number of id	14,343	14,343	14,343	14,343	14,343

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. The variable Farc represents the departments treated, taking the value of 1 if the department suffered greater violations in the ranking of human rights violated by the war in Colombia. The variable "Cease" refers to the beginning of the peace process negotiations in 2012. Column 1 presents the estimates using plant fixed effects. Column 2 shows White's robust variance correction, maintaining the plant fixed effects. Column 3 repeats the estimates from column 1 using bootstrap with 1000 replications. In column 4, department fixed effects are added to the estimates in column 2, and in column 5, plant fixed effects are added to the estimates in column 4. Source: Prepared by the authors based on the EAM 2000-2019.

Table 10. Effects of the peace process on the capital distortion (without the years 2020 and 2021)

$Ln(dK_{si})$	(1)	(2)	(3)	(4)	(5)
Farc	-0.171**	-0.171	-0.171	-2.066***	-1.950***
	(0.0666)	(0.135)	(0.132)	(0.0209)	(0.0244)
Cease	-0.145***	-0.145***	-0.145***	-0.139***	-0.0997***
	(0.00645)	(0.0128)	(0.0130)	(0.0129)	(0.0127)
Farc*Cease	0.105***	0.105***	0.105***	0.0992***	0.0918***
	(0.0103)	(0.0208)	(0.0190)	(0.0209)	(0.0205)
Constant	3.081***	3.081***	3.081***	4.896***	4.624***
	(0.0267)	(0.0541)	(0.0540)	(0.156)	(0.165)
Observations	143,999	143,999	143,999	143,999	143,999
R-squared	0.004	0.004	0.004	0.005	0.065
Number of id	14,292	14,292	14,292	14,292	14,292

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. The variable Farc represents the departments treated, taking the value of 1 if the department suffered greater violations in the ranking of human rights violated by the war in Colombia. The variable "Cease" refers to the beginning of the peace process negotiations in 2012. Column 1 presents the estimates using plant fixed effects. Column 2 shows White's robust variance correction, maintaining the plant fixed effects. Column 3 repeats the estimates from column 1 using bootstrap with 1000 replications. In column 4, department fixed effects are added to the estimates in column 2, and in column 5, plant fixed effects are added to the estimates in column 4. Source: Prepared by the authors based on the EAM 2000-2019.

Table 11. Effects of the Peace Process on Physical Productivity (without the years 2020 and 2021)

$Ln(TFPQ_{si})$	(1)	(2)	(3)	(4)	(5)
Farc	-0.0528	-0.0528	-0.145	-0.711***	-0.758***
	(0.0876)	(0.177)	(0.126)	(0.0189)	(0.0224)
Cease	-0.269***	-0.269***	-0.256***	-0.247***	-0.251***
	(0.00849)	(0.0163)	(0.0135)	(0.0120)	(0.0121)
Farc*Cease	0.163***	0.163***	0.111***	0.102***	0.106***
	(0.0135)	(0.0251)	(0.0190)	(0.0189)	(0.0189)
Constant	7.628***	7.628***	0.484***	1.113***	1.106***
	(0.0352)	(0.0706)	(0.0511)	(0.138)	(0.140)
Observations	143,999	143,999	143,999	143,999	143,999
R-squared	0.008	0.008	0.015	0.017	0.019
Number of id	14,292	14,292	14,292	14,292	14,292

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. The variable Farc represents the departments treated, taking the value of 1 if the department suffered greater violations in the ranking of human rights violated by the war in Colombia. The variable "Cease" refers to the beginning of the peace process negotiations in 2012. Column 1 presents the estimates using plant fixed effects. Column 2 shows White's robust variance correction, maintaining the plant fixed effects. Column 3 repeats the estimates from column 1 using bootstrap with 1000 replications. In column 4, department fixed effects are added to the estimates in column 2, and in column 5, plant fixed effects are added to the estimates in column 4. Source: Prepared by the authors based on the EAM 2000-2019.

Tables 9, 10, and 11 show the estimates excluding the years 2020 and 2021, which could affect the results due to the COVID-19 pandemic. All tables show that the coefficients are statistically significant and maintain their initial correlation. That is, output distortions decreased after the beginning of the peace process, capital distortion increased in response and total factor productivity of establishments increased in those departments most affected by the war compared to those of the control group.

Conclusions

In this research, using a standard model of monopolistic competition with heterogeneous firms, we estimated the impacts of the peace process initiated in Colombia in 2012 with the FARC guerrillas on the misallocation of plants located in the departments most affected by violence. For this purpose, both capital distortion and output distortion at the plant level were estimated. Also, the total productivity of physical and income factors was estimated.

Regarding output distortion, our results suggest that after the beginning of the peace process negotiations, there was a decrease in the output distortion of the plants located in the departments most affected by the war compared to the group of plants located in the less affected departments. However, the distortion of capital increased in those same plants after the beginning of the peace process. This can be explained by the inverse relationship between both indicators, i.e., with decreases in the distortion of the product and therefore of labor, there are increases in the distortions of capital.

Similarly, the impact of the peace process on total factor productivity (TFP) was evaluated. The results indicate that the peace process had a positive effect on the physical productivity of the plants located in the departments with the greatest presence of Colombian guerrillas, compared to the plants in the control group. This increase in productivity suggests that, with the peace process, firms located in the most affected departments were able to attract workers more economically and, simultaneously, reduce logistics and distribution costs due to the decrease in the activity of the armed groups. These changes translate into a more efficient use of inputs, reflected in increased firm productivity.

Robustness tests support the validity of these results, excluding possible biases introduced by high GDP departments or the effects of the COVID-19 pandemic. The coefficients of output, capital, and physical productivity distortion maintain their sign and statistical significance, corroborating the existence of a significant differential effect on these parameters. The findings of this paper highlight the importance of the peace treaty in Colombia and the importance of building policies that will bring a definitive end to the war in Colombia.

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