RESEARCH ARTICLE

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Labor Costs in Floriculture: The Link Between Pesticide Use and Occupational Cancer Risk

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Abstract

Objective: This article examines the financial impact of occupational cancer resulting from pesticide exposure and other carcinogenic agents in the floriculture sector of Cundinamarca, Colombia. It begins with a literature review covering (the) industry context, key occupational health factors, labor costs, and human capital. Based on this review, the study identifies gaps in the economic analysis of work-related illnesses such as cancer, particularly regarding hidden costs. **Method:** Using a quantitative explanatory approach, the research applies a multiple linear regression model to a dataset of 7,300 observations, analyzing absenteeism, labor costs, and worked days in relation to productivity. **Results:** The findings show a (59%) drop in productivity per diagnosed worker, leading to increased costs. The model yields an R^2 of (0.876), statistically supporting the hypothesis. **Conclusion:** The study confirms the existence of hidden costs such as absenteeism, employee replacement, and medical expenses that are not reflected in financial statements.

Keywords: floriculture- occupational cancer- pesticides- labor costs- linear regression- Colombia

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Introduction

Floriculture is one of the most important sectors for job creation both formal and informal within the Colombian economy. With an average of 14 to 16 workers per hectare, it has one of the highest employment rates in the agricultural sector. Most production is concentrated in the departments of Cundinamarca and Antioquia. Over the past decade (2014–2024), the industry has experienced strong growth thanks to technological advances, artificial intelligence, and more efficient use of inputs. These improvements have boosted export volumes and strengthened the sector's contribution to the economic, social, and labor development of these regions [1].

Despite these gains, the industry faces a major challenge: the intensive use of pesticides and chemical fertilizers. While these inputs help improve crop quality and yield, they pose serious health risks to workers. Prolonged exposure to such substances has been linked to occupational diseases, particularly work-related cancer a condition that not only threatens workers' health but also creates financial burdens for companies [2].

By 2025, production costs are expected to rise further due to increased fertilizer prices especially for products imported from Ukraine and Russia. According to agricultural land use surveys, approximately 84,744 hectares have been covered with plant waste, increasing potential harm to nearby families, both at home and at work [3].

Rising input costs are only one part of the picture. Production costs also include labor, which consists of both direct and indirect components. Among the latter are the social costs of workplace accidents. According to Heinrich's theory, there's a 1:4 ratio between direct and indirect costs meaning for every unit spent directly, four more are spent indirectly [4].

These indirect costs also relate to training, health, and education. According to economist Gary Becker's theory, investing in these areas can improve productivity. In contrast, occupational cancer reduces productivity, drives up labor costs, and slows economic growth. In this context, such illnesses affect not only the individual worker but also the company's and sector's overall human capital. The result isn't just absenteeism or high turnover it's a structural loss of productive capacity, harming both businesses and the broader economy [5].

This article aims to examine the relationship between pesticide and carcinogen exposure and its effect on production costs especially those related to labor. It evaluates how this issue affects productivity and operating costs by analyzing variables such as absenteeism, total labor costs, and job tenure in relation to output. A statistical model using R^2 (result: 0.876) confirms the significance of this effect and supports the hypothesis.

The findings offer empirical evidence of the economic consequences of work-related cancer. They show how deteriorating occupational health increases production costs. Ultimately, this study contributes to the discussion

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on the need for comprehensive policies that balance sector competitiveness with worker health protections. It advocates for sustainable practices that benefit both the industry and its employees. While previous studies have addressed clinical and epidemiological aspects of occupational illnesses, this article focuses specifically on occupational cancer in the floriculture sector, analyzing the economic, financial, and productivity-related implications—including hidden costs. By doing so, it bridges the gap between economic theory and the real-world consequences of occupational health risks in this industry.

Theoretical Framework

The Floriculture Sector

According to recent data [6], floriculture continues to be a key sector in Latin America, particularly in Colombia and Ecuador. Cost structure plays a decisive role in determining the sector's profitability and competitiveness. Reports show a 5.2% annual increase in production costs, driven by inflation, higher input prices, labor expenses, and medical compensation all of which directly impact profit margins.

Complementary information from [7] offers a detailed breakdown of production costs by crop type. This data not only helps calculate profitability margins but also allows for the analysis of investment allocation in inputs, fertilizers, labor, and technology. Along the same lines, Colombia's Ministry of Environment and Sustainable Development [8] has introduced circular economy guidelines, encouraging practices such as wastewater reuse, composting, renewable energy adoption, and safe chemical management to boost operational sustainability.

However, a core dilemma persists in floriculture: balancing productivity and worker health. As Arenas et al. [9] show, while technological innovations have improved flower quality and yield, they've also introduced new occupational and environmental risks. This contradiction even applies to supposedly sustainable practices, where environmental benefits may be offset by adverse health outcomes. The industry thus urgently needs protocols that align competitiveness with comprehensive safety.

Environmentally, Fields & Criscione [10] studied stratified substrate systems that enhance water retention. These systems significantly improved floral traits like size and durability in petunias, but the disposal of pesticide-contaminated substrate layers produced toxic vapors affecting nearby communities. This highlights the urgent need for safer disposal methods.

Among sustainability initiatives, the Sustainable Development Goals (SDGs) have encouraged biodegradable flower pots. However, Jaya et al. [11] point to a paradox: despite environmental benefits, these biopolymers may pose new public health risks, underlining the need for more comprehensive impact assessments. Similar contradictions emerge in edible floriculture. Gonçalves et al. [12] show that ammonium nitrate significantly boosts flower growth, yet its potential health risks remain underestimated. This reflects a broader pattern in intensive farming, where short-term productivity gains often overshadow long-term health concerns. Silicon use is another concern. While Kumari et al. [13] highlight its productivity and economic benefits, they also link it to serious pulmonary and renal diseases. This duality forces the sector to weigh commercial advantages against health risks for both workers and consumers.

Looking back, Meirelles et al. [14] had already identified risks in modern agricultural practices. Their study on wastewater use in horticulture found that, despite boosting yields, these techniques introduced health hazards when contaminated produce lacked proper traceability. Earlier, Bizari & Cardoso [15] documented the dangers of reusing contaminated irrigation water. Their research revealed how inadequate treatment systems could turn seemingly sustainable practices into public health threats, especially in urban farming environments. Cuquel et al. [16] also addressed input-related risks, showing the effectiveness of certain pesticides while exposing dangers from components like Osmocote. Despite being classified as carcinogenic, such substances remain widely used for their floral productivity gains.

Efforts to reduce these impacts include the work of Lee & González [17] at Ceniflores, which fostered collaboration between researchers and producers to improve production while lowering agrochemical exposure. Yet, these initiatives still fall short given the scale of the problem. Colombia's floriculture industry generates over 200,000 direct and indirect jobs, solidifying its role in national agriculture. However, it faces a critical paradox: the need to increase productivity while managing occupational diseases linked to pesticide use, particularly cancers affecting the skin and lungs. Although chemical agents boost yield and quality, they expose workers to toxic substances. Scientific evidence confirms a link between these compounds and chronic diseases, including cancer. This isn't just a personal issue—it imposes high economic and social costs on both employees and employers through absenteeism, medical leave, and replacement costs. These factors raise labor-related production costs, ultimately burdening public health systems and the national economy [18].

Pesticides and Health Risks

Prolonged pesticide exposure in floriculture poses serious health risks. Multiple studies have established strong correlations between such exposure and increased rates of various cancers, including non-Hodgkin lymphoma, multiple myeloma, and leukemia—especially among workers handling chemicals without proper protective equipment [19]. The situation is worsened by poor ventilation, direct contact with toxins, and a general lack of training and personal protection.

Beyond cancer, workers often suffer from acute symptoms such as dizziness, chronic headaches, and fatigue, which may develop into severe neurological issues [20]. These health effects are amplified by limited safety training and the absence of strict protocols. The issue extends beyond the workplace, becoming a public health concern in flower-growing regions where access to medical surveillance is minimal.

While some researchers point to genetic predispositions or lifestyle factors as contributors [21], these do not excuse the sector from implementing stronger preventive measures.

Labor Costs

Every product or service results from a production process that involves not just raw materials but also labor. Labor costs include wages, salaries, overtime, benefits, and social security (covering health, pensions, and workplace insurance). These benefits, however, only apply to formal workers; informal laborers bear these costs themselves.

Costs are generally categorized as fixed (always present) or variable (dependent on production volume). They can also be visible (wages, social security) or invisible, such as reputational damage, occupational disease compensation, training, replacements, rework, and first aid—all of which affect productivity [22].

Leigh et al. [23] argue that management decisions play a major role in unsafe conditions, waste, and contamination. They outline a three-step costing method [24]:

Identify damage costs (lost time, medical expenses, absenteeism);
Analyze root causes;
Quantify the cost per worker to determine the total economic impact.

Proper costing requires tools and procedures that economically evaluate occupational health risks. These "invisible" costs directly impact productivity and profitability [25].

As Bonilla et al. [26] note, hidden costs often exceed direct medical expenses by over 30%, including replacement training and productivity loss. However, Somavia [27] points out that financial reports often overlook these costs, distorting the company's economic reality and hindering effective prevention strategies.

Despite their importance, many organizations neglect to quantify occupational disease costs. Though several methodologies exist, few firms apply them consistently. This study introduces applicable methods across sectors and proposes a specialized econometric model to validate the research hypothesis and provide concrete tools for managing hidden labor costs:

a. Proportional Costing Method (H.W. Heinrich): Measures accident costs that may lead to chronic conditions, using indicators like lost time, affected workers, social security payments, unrealized production, rehabilitation, and overall profitability loss [28].

b. Economic Impact Estimation Method (Rollin H. Simonds): Differentiates between insured and uninsured costs. Ratios under 1 indicate reduced worker productivity. Key variables include lost-time wages, overtime, remote work costs, replacement training, social security-covered medical expenses, and productivity loss [29].

c. INSST Model: Developed in Peru, this online tool estimates the economic cost of workplace accidents and diseases under local regulations, offering a breakdown of total and individual components [30].

d. Economic and Non-Economic Cost Model [31]: Includes lost productivity, market performance, pain and suffering, reduced functionality, and quality of life. It assesses who the company, worker, or public health system ultimately absorbs each cost.

Unlike these models, which focus on general occupational conditions, our econometric model targets the specific economic impact of occupational cancer in floriculture. Unlike acute events, cancer has prolonged effects, influencing the worker, company, and even the family. Our model aims to:

Quantify productivity loss per affected worker;
Estimate cumulative business costs;
Statistically validate the link between cancer diagnoses and organizational performance.

Early results show significant patterns, which we will detail in later sections

Economically and accounting-wise, production costs determine fixed and variable cost drivers. Competitiveness is shaped not just by traditional costs but also by innovation, infrastructure, labor conditions, environmental regulations, and SDG alignment. Calderón et al. [32] argue that strategic cost systems improve production processes, adopt efficient technologies, reduce waste, and minimize workplace accidents. These systems also support export capabilities through comparative advantages and maximize economic and productive output in line with the SDGs.

Social Costs

Production-related costs typically include materials, inputs, and labor. However, "social costs" refer to broader societal effects of economic activities—not just those borne by producers but also by unrelated individuals or communities. These often invisible costs include legal expenses, treatment and rehabilitation, and family impact [33].

Jung et al. [4] emphasizes the importance of accounting for invisible costs in workplace accidents and illnesses. Hinz et al. [34] add that beyond lost productivity, organizations face lower output and high retraining costs for temporary replacements. This creates emotional, psychological, and financial strain for families [35]. For instance, workplace accidents cost the UK around £800 million in 2004, Estonia €2.4 billion in 2012, and Germany €18 million from 2011–2020 [36]. Gary Becker's human capital theory (1964) explains how productivity rises with investment in training and development. Companies that invest in health and safety reduce absenteeism and increase returns [5, 25].

Behind every worker diagnosed with occupational cancer lies a series of missed interventions. Investing in human capital means promoting training, safety, and healthy environments. Failing to do so leads to hidden costs like absenteeism, turnover, and declining productivity. These may not appear immediately in financial statements but have long-term effects. As Heinrich and Becker's theories suggest, unsafe environments damage productivity, while poor working conditions result in higher medical and legal costs, lost skills, and lower motivation [37].

In conclusion, occupational cancer is among the costliest workplace diseases. It undermines productivity, thrives in unsafe environments, and despite abundant literature, remains underexplored from an economic perspective. Most studies focus on clinical and epidemiological aspects, overlooking financial costs, productivity loss, staff turnover, human capital erosion, and workplace climate deterioration.

Materials and Methods

Methodology

This study adopts an explanatory quantitative approach, applying econometric techniques to analyze the relationship between economic and productivity variables and specific occupational health events, such as occupational cancer diagnoses. Using sectoral data from the Colombian Agricultural Institute (ICA) and the Colombian Flower Innovation Center (CENIFLORES), a representative sample was drawn from floriculture companies in Cundinamarca, particularly those located in the Bogotá savanna, the country's main flower-producing area [38].

Data

As of February 2024, the ICA reported 825 registered flower stem and cut-flower exporting companies in Colombia, with Cundinamarca and Antioquia hosting the largest numbers. Data from CENIFLORES indicate that in the Bogotá savanna and Cundinamarca, there are approximately 531 flower farms occupying about 5,407 hectares. Favorable geographic and climatic conditions in the region support high-quality production of flowers such as hydrangeas, roses, carnations, and chrysanthemums [38, 39].

Based on these figures, the study selected a representative sample to collect data for building a model that examines how occupational cancer diagnoses in floriculture workers affect both individual productivity and production costs especially labor-related expenses. These costs include absenteeism for medical treatment, higher medical expenses, additional wage payments to compensate diagnosed workers, and extra training costs for replacements. The model aims to determine how these cost increases reduce both worker productivity and overall company profitability, even when adequate occupational health and safety systems are in place. Due to the continued use of chemicals and pesticides to enhance flower quality, eliminating these risks entirely remains challenging.

For this initial analysis, a multiple linear regression model was developed. The dependent variable is monthly foliage production (in tons), and the following equation was formulated:

$$\text{Production} = \beta o + \beta 1 * CA + \beta 2 * CT + \beta 3 * DA + \beta 4 * CIM + \beta 5 * AG + \beta 6 * A + \beta 7 * DT + \varepsilon$$

Where:

Production: Monthly foliage output in tons (dependent variable)

CA (X1): Cancer diagnosis (1 = yes, 0 = no)

CT (X2): Total labor costs

DA (X3): Days of absenteeism

CIM (X4): Additional payroll and compensation costs

AG (X5): Seniority (1 = more than 7 years, 0 = less)

A (X6): Work area (1 = production, 0 = non-production)

DT (X7): Actual workdays

ε: Estimated error term

Type, Scope, and Design

This research is quantitative, based on data collected from floriculture companies in the Bogotá savanna. Its scope is explanatory, aiming to identify and analyze the effects of occupational cancer diagnoses on economic variables such as production, productivity, and labor costs. The study uses a non-experimental, cross-sectional design, meaning that variables are not manipulated but observed as they naturally occur. This allows for causal relationships to be analyzed through multiple linear regression modeling.

Procedure

To validate the model and ensure data reliability, the following steps were taken:

Training and testing validation: To avoid overfitting, the dataset was split into 70% for training and 30% for testing, allowing model evaluation through R^2.

Data normalization

Logarithmic transformations were applied to both dependent and independent variables to stabilize variance, approximate a normal distribution, and meet classical regression assumptions. This helped correct skewed data and improve model residual distribution.

Variable selection

Multiple combinations of explanatory variables were tested, evaluating coefficients and statistical significance to determine each variable's effect on the dependent variable.

Correlation matrix

A correlation matrix was created to check for multicollinearity among independent variables.

Diagnostic tests: Durbin-Watson tests for autocorrelation and Omnibus tests for normality were conducted.

Ordinary Least Squares (OLS) estimation: The final model used OLS to analyze production-related variables in the floriculture sector. The dataset included 7,300 observations from 50 workers across various companies and roles.

Time frame: Monthly production and cost data were collected from 2013 to 2023.

Data Analysis

A multiple linear regression model with natural logarithmic transformations was used to improve coefficient interpretation and reduce heteroscedasticity (uneven error variance). This normalization corrected skewed variables, such as absenteeism and labor costs, enabling better alignment and model fit. Log transformation also allowed the coefficients to be interpreted as elasticities: a percentage change in the dependent variable corresponds to a percentage change in an independent variable.

The data were processed using an econometric model in R and Python, validating classical assumptions including residual normality, homoscedasticity, and multicollinearity. This ensured model robustness and controlled for extreme variability across measurement units.

Ethical Considerations

This research was conducted in accordance with core ethical principles, including respect, confidentiality, and the responsible use of information. In the case of data related to workers diagnosed with occupational cancer, all information was fully anonymized, ensuring the absence of any personally identifiable elements.

Similarly, the financial data of participating companies was managed under formal confidentiality agreements, which prohibit the disclosure of real names or sensitive identifiers. All information used was obtained from secondary institutional sources and production records and was utilized exclusively for academic and research purposes.

Strict measures were taken to safeguard sensitive data, and all procedures complied with both national and international ethical standards governing scientific research, particularly in the fields of occupational health and labour economics.

Results

Model

The model does not show any evident violations of the classical assumptions of linear regression. The Jarque–Bera normality test yielded a statistic of JB = 1.1770 with a p-value of 0.5, indicating failure to reject the null hypothesis of normal distribution. Thus, there is no statistical evidence suggesting that the residuals deviate from normality. Regarding the independence of residuals, the Durbin–Watson statistic (DW = 1.984) falls within the acceptable reference range of $1.5 < DW < 2.5$, suggesting the absence of first-order autocorrelation. In terms of multicollinearity, the condition number (Cond. N. = 9.15) is well below the critical threshold of 10, and all variance inflation factors (VIFs) are below 5. This confirms a low level of collinearity among the independent variables and rules out serious multicollinearity issues. Furthermore, the use of the HC3 heteroskedasticity-consistent covariance matrix estimator provides robust standard errors and p-values, accommodating potential heteroskedasticity [40]. This enhances the reliability of statistical inference without fully relying on the assumption of constant variance.

The results of the model confirm the reliability and robustness of the data, providing a clear explanation of monthly production patterns in the floriculture sector of Cundinamarca. The analysis focused on how production costs specifically labor-related costs are influenced by absenteeism, training, hours worked, and the number of employees undergoing medical treatment following a cancer diagnosis. The types of occupational cancer considered in this study include laryngeal, bronchial, skin, and lymphatic cancers, based on research by Restrepo

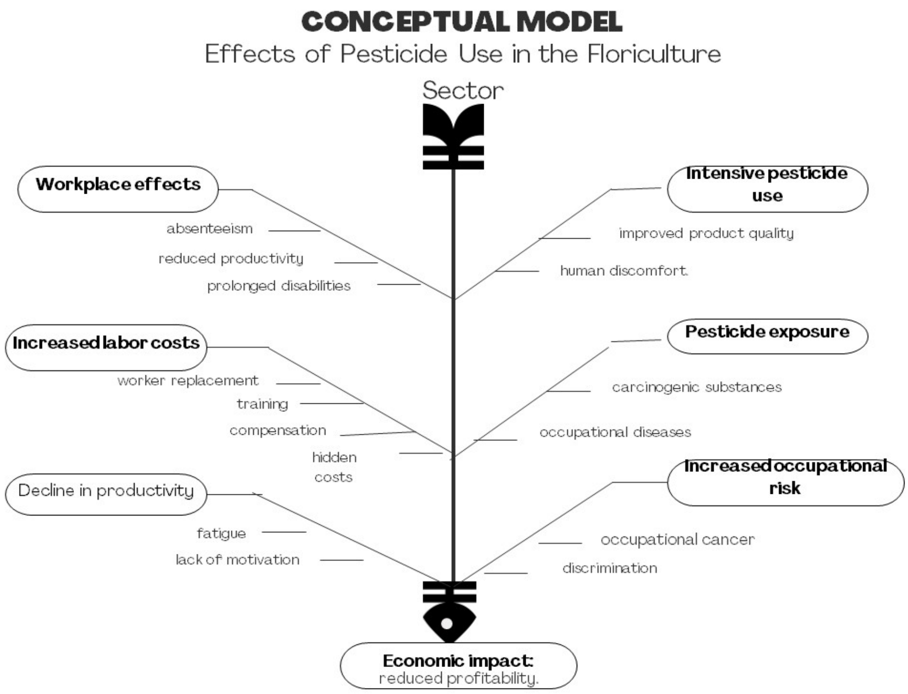

Figure 1. Causal Relationship: Occupational Cancer. Note. Figure 1 presents a conceptual model that illustrates the sequence generated by pesticide use in the floriculture sector, the associated risk, the resulting labour consequences, the relationship with labour costs, and the overall impact on productivity. Own elaboration

et al. [41], which identified a significantly high risk among floriculture workers for spontaneous abortions, congenital defects, and skin and laryngeal lymphomas. Hernández & Flórez [42] also highlighted dermatological, musculoskeletal, and respiratory conditions that could lead to cancer due to prolonged chemical and pesticide exposure in the floriculture industry. Furthermore, a recent publication by the Universidad Nacional updated the list of occupational carcinogens, naming the neck, lungs, and skin as the most commonly affected organs in the studied sector [43].

After analyzing the dataset, a multiple linear regression model was applied. Logarithmic transformations were used on some independent variables to correct for non-normality and heteroscedasticity, improving model balance and the statistical significance of predictors. The model demonstrated acceptable fit and interpretability for a linear regression.

The first step involved constructing a correlation matrix to check for strong relationships among predictor variables. This helped eliminate redundant variables, ensure relative independence, and reduce multicollinearity thus improving model quality and interpretability.

The model results show a coefficient of determination (R^2) of 87.6%, which reflects the proportion of variability in monthly production levels (in tons) explained by the independent variables. The adjusted R^2 is 87.3%, which enables comparison with other models that use a different number of predictors. The small difference (less than 1%) suggests the model does not include an excess of non-explanatory variables. The F-statistic of 120.4 is statistically significant, allowing rejection of the null hypothesis and confirming that at least one independent variable significantly affects production. The AIC (1.080e+05) and BIC (1.081e+05) values measure the model's goodness of fit. The coefficients represent the expected change in the dependent variable given a one-unit increase in each predictor [44].

The intercept indicates the expected production level when all independent variables are zero. Although its standard error (1.17) is relatively higher than others due to the intercept's theoretical nature as a baseline its statistical significance (p = 0.003) confirms that it is both robust and relevant for the model [45].

The regression model identifies significant predictors of production levels, such as social security costs and payments for absenteeism, both of which have a positive effect on production costs (i.e., an increase). The highly significant F-statistic supports the validity of the dependent variable. The low AIC and BIC values suggest a well-balanced model, while the low individual coefficient values imply meaningful impacts on production. Removing the variable CAAL might improve the model's performance and strengthen the hypothesis.

Table 1. Model

OLS Regression Results						
Dep. Variable:		Production		R-squared:		0.876
Model:		OLS		Adj. R-squared:		0.873
Method:	Least Squares			F-Static:		120.4
Date:	Wed, 11 Jun 2025			Prob (F-static):		3.45E-10
Time:		21:11:17		Log-Likelihood		-54001.1
No. Observations:		7300		AIC:		1.08E+05
Df Residuals:		7292		BIC:		1.08E+05
Df Model:		7				
Covariance Type:		HC3				
	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	2.179	1.171	1.861	0.003	-0.116	4.474
x1	-0.891	0.200	-4.455	0.001	1.283	-0.499
x2	0.501	0.080	6.263	0.001	0.344	0.658
x3	-0.292	0.100	-2.920	0.002	-0.488	-0.096
x4	-0.300	0.045	-6.726	0.001	0.387	-0.213
x5	-0.280	0.037	-7.533	0.001	-0.353	-0.207
x6	-0.356	0.051	-6.939	0.000	-0.457	-0.255
x7	0.172	0.032	5.453	0.003	0.110	0.234
Omnibus:		2.531		Durbin-Watson:		1.984
Prob (Omnibus)		0.271		Jarque-Bera (JB):		1.170
Skew:		-0.226		Prob (JB)		0.500
Kurtosis:		3.111		Cond. No.		9.150

Note: The table above presents the results of the regression model based on data collected from companies in the sector. It highlights that total costs and compensation costs which include expenses such as labour payments, social security contributions, and benefits for replacement workers, as well as indemnities paid to workers are key indicators explaining variation in production levels. The model specifically considers cancer diagnosis as a negative factor affecting worker productivity, with statistically significant effects. These results emphasize the economic impact of occupational health conditions on firms' output. The table is based on the authors' own calculations derived from the regression model results.

Table 2. Regression Coefficients and Interpretation

Variable	Coefficient	Interpretation	Supports Hypothesis
Intercept	2,179	Baseline value of log(Production) when all independent variables are zero. In original scale: $e^{2.179} \approx 8.83$ units.	Yes (positive effect)
Cancer (X1)	-0.891 (p = 0.001)	Workers diagnosed with cancer produce 59% less (calculated as $(e^{-0.891} - 1) \times 100$).	Yes (strong negative effect)
Log Total Costs (X2)	0.501 (p = 0.001)	A 1% increase in total costs is associated with a 0.501% increase in production (interpreted as elasticity).	Yes (positive effect)
Log Absence Days (X3)	-0.292 (p = 0.002)	A 1% increase in absence days leads to a 0.252% decrease in production.	Yes (negative effect)
Compensation Costs (X4)	-0.300 (p = 0.001)	A 1% increase in compensation costs leads to a 0.300% decrease in production.	Yes (negative effect)
Seniority (X5)	-0.280 (p = 0.001)	More senior workers produce 24.4% less $(e^{-0.280} - 1) \times 100$, possibly due to higher health risk accumulation.	Yes (negative effect)
Production Area (X6)	-0.356 (p = 0.000)	Workers in the production area produce 30.0% less $(e^{-0.356} - 1) \times 100$, possibly reflecting higher risk exposure.	Yes (negative effect)
Working Days per Month (X7)	0.172 (p = 0.003)	A 1% increase in the number of working days leads to a 0.172% increase in production.	Yes (positive relationship)

Note: The table above presents the results of the regression model based on data collected from companies in the sector. It highlights that total costs and compensation costs which include expenses such as labour payments, social security contributions, and benefits for replacement workers, as well as indemnities paid to workers are key indicators explaining variation in production levels. The model specifically considers cancer diagnosis as a negative factor affecting worker productivity, with statistically significant effects. These results emphasize the economic impact of occupational health conditions on firms' output. The table is based on the authors' own calculations derived from the regression model results

Furthermore, the statistical evidence confirms a potential increase in production costs when occupational cancer-related expenses rise in the sector.

Hypothesis Validation

The main hypothesis "There is a negative variation in labor productivity when a cancer diagnosis is reported" is addressed through the information presented in Table 1.

The secondary hypothesis states that a worker diagnosed with cancer reduces production by approximately 59%, ceteris paribus. This implies that, on average, the productivity of a worker with cancer is less than half that of a worker without any such diagnosis. The 95% confidence interval for the coefficient in logarithmic scale is (-1.283, -0.499), which translates to a reduction in production ranging from 72% to 39%. The coefficient is highly significant ($p < 0.01$), indicating that this negative effect is statistically robust and unlikely to be due to random variation.

Discussion

The results of this research confirm previous findings in the literature regarding the use of pesticides and carcinogenic substances in the floriculture sector. Studies such as those by Pedroso et al. [19] and Villegas Narváez & Montero Reyes [20] report a strong correlation between occupational exposure to these substances and the incidence of occupational cancers particularly skin, lymphatic, and lung cancers which are also examined in this study.

Moreover, the econometric model supports the conclusions of Bonilla et al. [26] and Somavia [27], who emphasized the existence of invisible costs associated with occupational illnesses. These include extended absenteeism, temporary replacements, productivity losses, and a deterioration in organizational climate. Although these costs are not explicitly reflected in financial statements, they significantly impact indicators such as productivity, turnover, and profitability. The model's finding a 59% average reduction in the productivity of an affected worker aligns with Becker's (1964) theory on the loss of human capital due to illness.

The study also reinforces the observations of Restrepo et al.[41] and Henríquez et al. [43] regarding the most prevalent cancer types in the floriculture industry. It further echoes the insights of Battistuzzi [46], who pointed out that pre-existing conditions and prolonged exposure to carcinogens are likely to be well-established risk factors.

Unlike many previous studies that focus solely on the clinical or epidemiological implications of occupational cancer, this research offers a novel perspective by examining the production cost implications and their relationship with workforce productivity. While studies like that of Oirdi et al. [47] have analyzed the environmental impact of pesticide use or the harm to surrounding communities, this paper centers its analysis on economic outcomes within the companies themselves. As such, it contributes a new lens to sustainability analysis grounded in occupational health.

Although earlier works by Dorman [31] and Carrillo & Dieste [28] proposed theoretical models to estimate the costs of occupational illnesses, none applied these frameworks specifically to occupational cancer or to Colombia's floriculture sector. In this regard, the present study represents a pioneering econometric approach to this pressing issue.

In conclusions, the linear regression model applied in this study confirms that an occupational cancer diagnosis significantly increases labor costs, thereby reducing the profitability of companies in the floriculture sector. This finding validates the initial hypothesis regarding the economic impact of such diseases on production structures. Improper management of pesticides and chemical substances affects not only workers and employers but also the entire sector's value chain, compromising competitiveness and long-term sustainability.

Based on these findings, it is recommended to promote integrated policies that balance productive innovation with socio-environmental responsibility. Priority should be given to the adoption of cleaner technologies, strict safety protocols, and preventive health programs for workers. This requires coordinated efforts among the public sector, private companies, and academia. Special attention should be given to the well-being of floriculture families the human foundation of this industry particularly in regions like Cundinamarca, where the sector's impact is most concentrated. Only through a systemic approach that protects both productivity and health can a sustainable future for this strategic sector in Colombia be ensured.

This research also contributes to the fields of occupational health and labor economics by linking both areas through a human capital perspective and by revealing the so-called "invisible costs" ignored in financial statements. The model and literature findings highlight how workers' deteriorating health results in subtle yet significant losses such as reduced productivity, increased turnover, compensated days, or extra costs due to extended absences that are not captured in conventional accounting.

Additionally, the study identified barriers to the collection of primary data. Financial statements often do not reflect invisible costs, and their estimation required cross-referencing payroll and financial records along with interviews with internal staff. Furthermore, some employees were hesitant to disclose health information due to fear of retaliation, even when confidentiality agreements had been signed. In contrast, workers already diagnosed with cancer were generally more open and aware of the personal and organizational implications of lapses in personal protective equipment usage. Nonetheless, many companies do not acknowledge a direct link between working conditions and cancer diagnoses, which complicates the traceability of occupational disease origins.

This investigation opens multiple lines for future research. Expanding the analysis to regions like Antioquia or other significant floriculture zones would allow for interregional comparisons. It is also recommended to explore similar risks in other agro-industrial sectors. Lastly, collaborative studies involving industry associations, insurers, and medical institutions could help generate shared data that enhances transparency and promotes the formal recognition of occupational illnesses, particularly occupational cancer.

Author Contribution Statement

All authors contributed equally in this study.

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None.

References

1. Semana. The floriculture sector generates around 200,000 jobs, 60% of which are held by women. Semana.Com latest news from colombia and the world. Economic desk. (2024, february 14). Available from: Https://www.Semana.Com/economia/articulo/el-sector-floricultor-genera-alrededor-de-200-mil-empleos-de-los-cuales-el-60-son-ocupados-por-mujeres/202459/.
2. Páez a. Colombian floriculture. Adama. (2023, september 12). Available from: Https://www.Adama.Com/colombia/es/sostenibilidad/la-floricultura-colombiana.
3. Ocs. (2025, january 17). Farm structure survey 2023. Ocs. Available from: Https://www.Cso.Ie/en/releasesandpublications/ep/p-fss/farmstructuresurvey2023/soilmanagement/.
4. Jung C, Baek Jong B. A study on the importance of uninsured (indirect) cost item of workplace accidents. Korean Chem Eng Res. 2017;50. https://doi.org/10.9713/kcer.2017.55.4.497.
5. Burt RS. Structural holes. In routledge (ed.), social stratification: Class, race, and gender in sociological perspectivebook; 2018. (4th ed., p. 5).
6. Corficolombiana. Las flores en tiempos de san valentín: The strategic importance of colombian floriculture; 2025. Available from: Https://investigaciones.Corfi.Com/documents/38211/0/2025-02-14 informe especial flores f.Pdf.
7. Fira. Fira will encourage the use of sustainable technological innovations in agriculture. Fideicomisos instituidos en relación con la agricultura; 2025.
8. Ministry of environment and sustainable development. Environmental guide for flower and ornamental species cultivation with a circular economy approach; 2025. Available from: Https://www.Minambiente.Gov.Co/wp-content/uploads/2025/01/guia-ambiental-flores-y-ormanentales_digital-1-1.Pdf.
9. Arenas CN, Bello AP, Molina NF, Botero JL, Betancur M. Life cycle assessment and life cycle costing for the production of hydrangeas in antioquia colombia. Agronomy. 2024;14(7):1408. https://doi.org/10.3390/agronomy14071408.
10. Fields Js, Criscione Ks. Stratified substrates can reduce peat use and improve root productivity in container crop production. Hortscience. 2023;58(3):364–372. Https://doi.Org/10.21273/hortsci17019-22.
11. Jaya Jd, Nugroho A, Elma M, Sunardi S. Review on biodegradable pot: A new promising approach for sustainable agriculture. Inaip conference proceedings 2023 feb 7 (vol. 2682, no. 1, p. 030009). Aip publishing llc.
12. Gonçalves J, Borges Júnior Jcf, Souza Fa De, Silva Apcm, Ferraz L De Cl. Production of edible flowers: Irrigation and biotechnology. Revista ceres. 2023;70(2):1–12. https://doi.org/10.1590/0034-737x202370020001.
13. Kumari P, Sharma R, Panwar S, Paul S, Banyal N. Silicon as vital element in flower crop production. J Plant Nutr. 2023;46(11):2747–2762. https://doi.org/10.1080/01904167.2022.2160739.

14. Meirelles AFM, Baldotto MA, Baldotto LEB. Produtividade da alface (lactuca sativa l.) em resposta à aplicação de ácidos húmicos e bactérias diazotróficas, em condições de campo. Revista ceres. 2017;64(5):553–556. https://doi.org/10.1590/0034-737x201764050014.
15. Bizari DR, Cardoso JC. Reuse water and urban horticulture: Alliance towards more sustainable cities. Hortic Bras. 2016;34(3):311–317. https://doi.org/10.1590/s0102-05362016003002.
16. Cuquel Fl, Polack SW, Favaretto N, Possamai JC. Fertigation and growing media for production of anthurium cut flower. Hortic Bras. 2012;30(2):279–285. Https://doi.Org/10.1590/s0102-05362012000200016.
17. Lee Ra, González C. Administrating a "virtual" research centre: The case of the colombian centre for innovation in floriculture. Incomputers in agriculture and natural resources, 23-25 july 2006, orlando florida 2006 (p. 557). American society of agricultural and biological engineers.
18. Mofidi A, Tompa E, Kalcevich C, Mcleod C, Lebeau M, Song C, et al. Occupational exposure to wood dust and the burden of nasopharynx and sinonasal cáncer in canada. Int J Environ Res Public Health. 2022;19(3):1144. Https://doi.org/10.3390/ijerph19031144.
19. Pedroso TMA, Benvindo-Souza M, De Araújo Nascimento F, Woch J, Dos Reis FG, De Melo ESD. Cancer and occupational exposure to pesticides: A bibliometric study of the past 10 years. Environ sci pollut res int. 2022;29(12):17464-75. https://doi.org/10.1007/s11356-021-17031-2.
20. Villegas narvaez lM, Montero reyes Y. Occupational safety in floriculture: Challenges and solutions to the use of pesticides. Sct proc. Interdiscip. Insights Innovs.2025;3:437. Https://doi.org/10.56294/piii2025437.
21. Mi W. Open access journal of agricultural research pesticides exposure in relevance to cáncer risk. Journal of agricultural research. 2017;1–6. Available from: Https://medwinpublishers.Com/oajar/oajar16000129.Pdf.
22. Fernandes MM, Ruiz MT, Mancera MR, Ruiz JR. Seguridad e higiene industrial, gestion del riegos. Editorial alfaomega, año; 2012.
23. Leigh JP, Markowitz SB, Fahs M, Shin C, Landrigan PJ. Occupational injury and illness in the united states. Estimates of costs, morbidity, and mortality. Archives of internal medicine. 1997;157(14):1557–1568.
24. Muñoz a, rodríguez j, martínez j. Industrial safety: Fundamentals and applications. 2023; availble from:Https://www.F2i2.Net/web/publicaciones/libro_seguridad_industrial/lsi.Pdf.
25. Gayá Pérez H, Torres Ordóñez Mb, Díaz P, Ramada JM, Serra CG, Benavides F. Estimación económica de una muestra de casos de enfermedad profesional confirmados por el instituto nacional de la seguridad social atendidos en el parc de salut mar, 2014-2021. Archivos de prevención de riesgos laborales. 2023;26(1):41–48. https://doi.org/10.12961/aprl.2023.26.01.04.
26. Bonilla V, Gallego M, Cerquera B, Alfredo R, Alfonso J, Rivelino F. Construcción habitacional, la mirada de los costos directos subjetivos como consecuencia de los accidentes laborales home building, direct subjective costs as a consequence of labor accidents eje temático: Riesgo de operativo y de negocio. In revista crecer empresarial: Journal of management and development. 2018.
27. Somavia J. Safety in figures: Suggestions for a global culture of safety at work: [world day for safety and health at work] (ilo, ed.; ilo, vol. 1). Ilo. 2023. Available from: Https://webapps.Ilo.Org/static/english/protection/safework/worldday/report_esp.Pdf.
28. Carrillo salomón R, Dieste Sánchez W. Current trends in the economic analysis of occupational morbidity. Cuban journal of hygiene and epidemiology. 2000;38(1):60-7.
29. Acevedo gonzález k, yánez contreras m. Costs of workplace accidents: Cartagena-colombia, psychological sciences, 10(issn 1688-4094). Available from: Http://www.Scielo.Edu.Uy/scielo.Php?Script=sci_arttext&pid=s1688-42212016000100004.
30. Rodríguez kb, marrugo ea. Estimation of the costs of work accidents and dangerous incidents in a company transporting hazardous materials and general cargo in the last three years (2017-may 2019). Aglala. 2022 dec 15;13(2):63-72.
31. Dorman P. The economics of safety, health, and well-being at work: An overview. Geneva: Ilo; 2000 may.
32. Calderón L, Guerra V, Gallejos M, Beltran LI. Competitividad del sector floricultor mediante la estrategia liderazgo en costos. Espacios. 2025;42(20):13–23. Https://doi.org/10.48082/espacios-a21v42n20p02.
33. Hedlund J, Metz F, Bodin Ö. Networking strategies for coordinating interdependent policy issues: A motif approach. Policy Stud J. 2025. https://doi.org/10.1111/psj.12588.
34. Hinz N, Dehoust J, Seide K, Kowald B, Mangelsdorf S, Frosch KH, Hartel MJ. Epidemiology and socioeconomic consequences of work-related pelvic and acetabular fractures recorded in the german social accident insurance. Injury. 2023;54(8):110848. Https://doi.org/10.1016/j.Injury.2023.110848.
35. Enn A, Merilasu E. The prevalence of work accidents in estonian agriculture in 2008–2017. Estonian academic agricultural society. 2024;30(special issue 2). Https://doi.org/10.15159/jas.19.11.
36. Millei Z. Governing the brain: New narratives of human capital in australian early childhood education. In global perspectives on human capital in early childhood education (pp. 47–69). Palgrave macmillan us. 2015. https://doi.org/10.1057/9781137490865_3.
37. Alshameri F, Salsi D, Yamine B. A case study of the socio-economic approach to management used for a lebanese entrepreneurial venture. Int J Bus Innov Res. 2025;36(2):170–185. Https://doi.org/10.1504/ijbir.2025.144386.
38. Ceniflores. Sector floricultor. Ceniflores; 2024. Available from: Https://ceniflores.Org/sector-floricultor/.
39. ICA. Axis 1. Contribution to comprehensive rural reform with emphasis on the... 2024; available from: Https://www.Ica.Gov.Co/modelo-de-p-y-g/transparencia-participacion-y-servicio-al-ciudada/rendicion-de-cuentas/informes-de-gestion/informe-de-gestion_210125-19022025.Aspx.
40. White H. A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity. Econometrica. 1990;48(4):817. https://doi.org/10.2307/1912934.
41. Restrepo M, Muñoz N, Day Ne, Parra Je, De Romero L, Nguyen-Dinh X. Prevalence of adverse reproductive outcomes in a population occupationally exposed to pesticides in colombia. Scand j work environ health. 1990;16(4):232-8. Https://doi.org/10.5271/sjweh.1790.
42. Hernández a, flórez j, suárez z. Health, work and capital: The case of women workers in the flower agro-industry of madrid, colombia, 2019-2020. Revista gerencia y política de salud. 2022;21. Available from: Https://revistas.Javeriana.Edu.Co/index.Php/gerepolsal/article/view/35679.
43. Henriquez G, Cruz F, Cortes C, Giraldo C. Carcinógenos ocupacionales relevantes en colombia, listado actualizado (2020). Revista de salud pública. 2022;23(4). Https://doi.org/10.15446/rsap.V23n4.85134.
44. Wooldridge jm. Econometric analysis of cross section and panel data (the mitt press). 2010.
45. Angrist JD, Pischke JS. Mostly harmless econometrics: An

empiricist's companion. Princeton university press; 2009 jan 4.
46. Battistuzzi l. The challenges of cascade genetic testing in hereditary cáncer syndromes: A few ethical considerations. Tumori j. 2024. Https://doi.Org/10.1177/03008916241297782.
47. Oirdi mel, yaseen m, farwa u, raza ma, farhan m, sandhu za, et al. Crops and people: The dangers and potential benefits of pesticides. Cogent food & agriculture. 2024;10(1). Https://doi.Org/10.1080/23311932.2024.2334096.