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Fixed or open-ended? Labor contract and productivity in the Colombian manufacturing sector

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Fixed or open-ended? Labor contract and productivity in the **Colombian manufacturing sector**

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ABSTRACT

Using the Colombian Annual Manufacturing Survey (AMS) between 2000 and 2014, this paper investigates the effect of labor contract modalities on firm productivity within the industrial sector through a structural model. We find that the elasticity of revenue with respect to temporary workers is often lower than that with respect to permanent workers, but not in small firms, where some forms of flexibility might lead to productivity gains.

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Labor contracts; temporary workers: skilled workers: firms' TFP

1. Introduction

Over the past few years, as a result of the waning commodity boom, Latin America (LA) has been grappling with the puzzle of growth. Productivity has not played a remarkable role in this quest for stronger economic performance and has contributed instead to the gap with more advanced economies. On average, LA labor productivity is less than 30% of US.¹

The growth of productivity in the economy as a whole depends not only on how fast productivity is rising in individual industries, but also on whether resources are moved in or out of those industries in response. Labor allocation and labor markets play an important role in it. Given the surge in temporary (fixed-term) modalities of contracting in advanced and emerging economies since the 1980s (Cazes & Laiglesia, 2015), the literature has investigated the effect of contractual terms on productivity growth.

This paper explores the relationship between labor contracts and firm productivity in the Colombian industrial sector, using the information of the Annual Manufacturing Survey (AMS). In Colombia (Figure 1, panel a), total employment in manufacturing passed from around 485,000 in 2000 to almost 584,000 in 2014.² Both workers with permanent (open-ended) contracts and workers with temporary (fixed term) contracts increased, but the share of temporary did so to a larger extent (Figure 1, panel b): in 2000, 25% of workers had temporary contracts vis- a vis 35% in 2014. When all economic sectors are considered, Colombia exhibits one of the highest shares of temporary workers

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Authors' calculations based on The Conference Board Total Economy Database, 2015.

²These figures refer to total employment in firms with more than 10 employees only.

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Figure 1. Total manufacturing employment. (a) Type of labor contract (b) Share of temporary contracts. Source: Dane-AMS; authors' calculations

if compared to the rest of Latin America and the Caribbean³ and OECD countries.⁴ This surge in temporary employment, often considered a way to curb high labor costs due to the rigidities of labor market regulations, has taken place across all subsectors within manufacturing, except basic metals (Figure 2).

While most firms in Colombia are small or medium, the large ones generate most of the employment and permanent positions. In 2014, 42% of permanent workers were hired by large plants, 38% by medium ones, 20% by small (Figure 3, panel a).⁵ However, the larger the plant, the smaller is the share of its permanent workers: 54% of the labor force has a permanent contract in large firms, with respect to 61% in medium, and 70% in small ones (Figure 3, panel b). Although large firms contribute the most to permanent positions, they hold lower shares of permanent workers. The percentage of plants hiring temporary workers also increases by plant size, and export status.⁶

Permanent workers are more likely to be skilled⁷ and larger plants exhibit slightly higher shares of skilled workers. Figure 4 depicts the share of skilled (vs. unskilled) workers by contract choice (panel A), by plant size (panel B), and by industry subsector (panel C). The comparison between Figures 2 and 4 shows that the subsectors with the highest share of skilled workers (petroleum products, chemicals, medical equipment) are also the ones with the highest proportion of permanent contracts, while the subsectors with the lowest shares (apparel, leather, textiles) are ones with the lowest proportion of skilled workers. This is in line with the hypothesis that, when technologies require a more skilled labor force, firms tend to hire on a longer-term basis as they value their workforce more (Eslava, Haltiwanger, Kugler, & Kugler, 2014).

³Source: national household surveys, 2015.

⁴Source: OECD Data, 2015.

⁵Firms are classified by size in small (between 10 and 49 employees), medium (between 50 and 200 employees), and large (more than 200 employees).

⁶94% of large firms has at least one worker with a temporary contract vs. 75% of medium-size firms, and 49% of small. Exporting firms are also more likely to be hiring temporary workers (78% of exporters hire temporary workers vs. 59% of non-exporters in 2014). Moreover, they tend to be larger in size, and with higher shares of temporary workers (37% of workers are temporary in exporting firms vs. 34% in non-exporters in 2014).

⁷44% of workers with permanent contracts is skilled vs. 28% of temporary workers.



Figure 2. Share of temporary contracts by subsector in 2000 and 2014. Source: Dane-AMS; authors' calculations.





Source: Dane-AMS; authors' calculations.

The reduction in the share of permanent workers between 2000 and 2014 may bear consequences for firm growth potential. The type of labor contract can affect workers' efforts through different channels. If a worker expects to stay in a workplace for a short period, her willingness to exert efforts might diminish, which in turn can negatively affect the firm's productivity. Moreover, the high turnover encouraged by temporary contracts





Share of Skilled Workers, 2014

Figure 4. Percentage of skilled and unskilled worker in 2014. (a) by contract choice (b) by plant size (c) by subsector.

Source: Dane-AMS; authors' calculations.

may limit incentives for job trainings, further harming productivity. On the other hand, a temporary worker might exert more effort to be rewarded with a contract renewal or with a permanent contract. Temporary contracts might also have a positive effect on productivity as they allow for more flexibility, facilitating firms' allocative efficiency (hiring the right worker at the right time) and allowing for an easier workforce adjustment when needed. In a nutshell, the labor contract choice can affect productivity in either direction.

As we can see from Table 1, temporary workers are more likely to be female, but significantly more so in larger firms only; they are also younger than permanent ones, irrespective of firm size, even though the gap in average age is greater in medium/large

				Small			Med	um/Large	
		Temporary	Permanent	Difference in Means	S.E.	Temporary	Permanent	Difference in Means	S.E.
Age		33.22	36.01	-2.797***	0.861	32.42	36.66	-4.241***	0.614
Female		40.50%	37.20%	3.2	4.280	40.40%	35.00%	5.4*	3.160
Education	Years of Education	10.13	10.97	-0.84**	0.346	11.23	11.93	-0.69***	0.198
	No Education	0.45%	0.30%	0.2	0.350	0.02%	0.60%	-0.6**	0.271
	Primary Incomplete	4.11%	4.27%	-0.2	1.720	1.28%	2.31%	-1.0	0.780
	Primary Complete	9.13%	8.07%	1.06	2.490	5.76%	4.59%	1.17	1.530
	Secundary Incomplete	24.10%	17.90%	6.2*	3.530	11.00%	9.04%	2	1.890
	Secundary Complete	35.40%	31.40%	3.9	3.910	44.10%	35.70%	8.3***	3.180
	Tertiary Incomplete	6.73%	7.33%	-0.6	2.470	11.10%	7.65%	3.4*	1.890
	Tertiary Complete	18.30%	29.60%	-1.13***	3.660	24.90%	38.70%	-1.39***	2.880
Occupation:	Vocational/Technician	6.02%	12.00%	-6.0**	2.370	12.40%	14.60%	-2.2	2.090
	Director or Senior Officer	4.45%	5.11%	-0.7	2.170	1.40%	6.13%	-4.7***	1.180
	Administrative or intermediate level	10.20%	13.50%	-3.3	2.910	15.20%	15.00%	0.2	2.430
	Retailers and Sellers	7.44%	6.17%	1.27	1.910	9.20%	12.50%	-3.3*	1.810
	In Services	4.48%	4.67%	-0.2	1.740	8.53%	6.70%	1.82	1.930
	Farm Workers	0.08%	0.17%	-0.1	0.190	1.12%	2.31%	-1.2	0.879
	Blue-Collar (outside agriculture)	66.80%	58.30%	8.5**	4.170	52.00%	41.70%	10.3***	3.210
	Other	0.52%	0.00%	0.5*	0.303	0.13%	1.04%	-0.9	0.673
Formal		54.40%	93.80%	-3.94***	3.310	89.60%	98.10%	-8.4***	1.840
Part time		1.52%	0.05%	1.5**	0.701	0.28%	0.29%	-0.00	0.282
Wage		865,656	1,395,000	-529,523***	176,055	1,017,000	1,735,000	-718,009***	114,893
Source: Colomb Notes: *p < 0.1,	ia Great Integrated Household Survey 2 **p < 0.05, ***p < 0.01.	2014; authors' ca	alculations.						

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firms.⁸ Besides being younger and female, temporary workers are also characterized by fewer years of education. Most of the workers in manufacturing are blue-collar and most of the blue-collar workers are hired through temporary contracts, across all firm sizes. A striking difference is the proportion of formal jobs among temporary workers in small firms, where only half are affiliated to or pay social security contributions. In larger firms, they are approximately 90%. Moreover, temporary workers are remunerated less than permanent ones, and the gap is larger in medium and large firms.⁹

In this paper, we investigate how hiring through temporary contracts affects plant productivity. By applying Addessi's (2014) model, we find that the elasticity of value added of temporary workers in the manufacturing sector is lower than that of permanent workers. This holds true in exporting and non-exporting plants, in medium and large plants, and in different geographical areas, and in most of the subsectors. However, in small plants and in a few subsectors, the elasticity of value added of temporary and permanent workers are not so different. A higher share of temporary workers in small size firms is even beneficial to TFP with a lag, while the opposite is true for larger firms. Our results are not driven by the difference in the skill composition of temporary and permanent workers, but by the contract modality itself.

The paper develops in seven sections beyond this introduction. The second section offers a brief literature review. The third presents the institutional background. The fourth provides the data description. The fifth explains the empirical model, and the sixth describes the results. The seventh section concludes. The Appendix contains detailed information on the data cleaning process and definitions of variables.

2. Literature review

Much of the literature on the relationship among labor markets and productivity relates to employment protection legislation (EPL)¹⁰ and to OECD countries,¹¹ without being conclusive on the effect of contract modalities on productivity, nor providing much evidence beyond the OECD.

Generally, research acknowledges that different labor contracts might imply different levels of productivity and finds that the use of, or the regulations related to the use of, temporary contracts can have negative or non-significant effects on firms' productivity (Addessi, 2014;¹² Bassanini, Nunziata, & Venn, 2009; Aguirregabiria & Alonso-Borrego,

⁸Source: Colombian Great Integrated Household Survey (Gran Encuesta Integrada de Hogares). We limit the sample to wage workers in the manufacturing sector between 15 and 64 years old in 2014. Given the way the survey was implemented, we are unable to distinguish between medium and large firms, so we will group the two categories together.

⁹The difference in pay could be a factor demotivating effort, hence the lower productivity level, but we cannot rule out the reverse causality either, i.e., that precisely because these workers are less productive, they are compensated with lower wages.

¹⁰The indicators of employment protection legislation (EPL) outline conditions under which workers can be hired on both regular and temporary contracts.

¹¹The Employment Protection Legislation (EPL) methodology developed by the Organization for Economic Cooperation and Development (OECD) measures the degree of stringency of employment protection legislation of OECD and G201 countries, to determine, amongst others, its labor market impacts. The Inter-American Development Bank (IDB), in collaboration with the OECD, has applied this methodology to Latin American and Caribbean (LAC) countries.

¹²Addessi (2014) develops a structural model that allows for the labor-contract choice to influence labor-augmenting factors and capture the effects on the evolution of the firm productivity process and finds the use of temporary contracts to be detrimental to TFP growth.

2014; Damiani & Pompei, 2010;¹³ Cappellari, Dell' Aringa, & Leonardi, 2012;¹⁴ Jona-Lasinio & Vallanti, 2011; Nielen & Schiersch, 2016).¹⁵ Dolado and Stucchi (2014) find that the effect of temporary contracts on TFP growth is negative when the conversion rate from temporary to permanent contracts is low, because the effort provided by temporary workers diminishes.

Using a natural experiment Autor and Houseman (2010) show that temporary-help positions reduce subsequent earnings and employment outcomes in the United States. With an eye to European labor markets, Blanchard and Landier (2002) and Cahuc and Postel-Vinay (2002) model temporary contracts as churning policies that affect negatively wage setting and may generate higher unemployment and lower productivity. According to Boeri and Garibaldi (2007), if fixed-term contracts are used as a bufferstock to boost the number of hiring in a boom, employment may go up at least temporarily, but they find the use of fixed-term contracts in Italy to be associated with lower average productivity. The model by Cahuc, Cheron, and Mahlebert (2016) shows that the substitution of temporary for permanent positions induced by job protection does not change much total employment but reduces aggregate productivity.

However, according to Ichino, Mealli, and Nannicini (2008) temporary contracts can be good screening devices and stepping-stones into permanent posts and therefore increase productivity. Giuliano, Kampelmann, Mahy, and Rycx (2017), while not finding any significant effect of hiring through fixed-term contracts on firm competitiveness in the Belgian manufacturing sector, observe a positive and significant effect on labor productivity in services, which they attribute to some service subsectors being more labor intensive, in need of less sophisticated technology and less able to create stocks. Finally, Eslava et al. (2014) find that in Colombia the use of temporary contracts is associated with higher firms' productivity, particularly in businesses with lower skill needs. In the latter, a more intensive use of fixed-term contracts plays as a shock absorber and leads to productivity gains. However, using fixed-term employment more intensively has a negative effect on TFP for the more high-skill intensity plants.

3. Institutional background

Colombia is characterized by a dual labor market, where workers are entitled to different employment protection depending on the contract they hold. Fixed-term contracts must be written and can last for a maximum duration of three years. However, they can be renewed indefinitely if they are of the duration of one-year (Articles 45 and 46 of the Labor Code). Open-ended contracts instead have no time limit.

¹³Damiani and Pompei (2010) analyze the effect of labor protection on Total Factor Productivity (TFP) growth in 18 European countries between 1995 and 2005. They also control for the effect of growth in temporary employment on TFP, ending a negative and significant relation.

¹⁴Cappellari et al. (2012) use 13,000 firm level observations of all Italian sectors between 2004 and 2007 to study the effects of deregulation reforms of apprenticeship and fixed-term contract. They find a small negative, but only weakly significant, effect of fixed-term employment on labor productivity, driven by the reduced job tenure and increased use of external collaborators that hampered the optimal allocation of resources.

¹⁵Bassanini et al. (2009) measure productivity as TFP and find no evidence of a productivity effect of facilitating the use of fixed-term contracts in the OECD; Damiani and Pompei (2010) find that fixed-term contracts can have detrimental effects on TFP growth; Jona-Lasinio and Vallanti (2011), Aguirregabiria and Alonso-Borrego (2014), and Nielen and Schiersch (2016) measure productivity as labor productivity.

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The other main difference is dismissal payment: the employer who decides to dismiss a worker hired through an open-ended contract faces a dismissal cost. The dismissal compensation varies depending on the monthly salary (Article 64 Labor Code):

- If remuneration is lower than 10 minimum legal monthly salaries:
 - o 30 days if tenure less than 1 year
 - o 20 extra days for each subsequent year and in proportion per fraction of year
- If remuneration is above 10 minimum legal monthly salaries:
 - o 20 days if tenure less than 1 year
 - o 15 extra days for each subsequent year and in proportion per fraction of year

On the contrary, workers hired through a temporary contract can be dismissed at the end of the contract without compensation.

Firms in Colombia can also hire workers through a temporary work agency for services required on occasional, accidental, or transitory basis, to replace workers which are on vacation, maternity, or sickness leaves, to attend an increase in production, transport, sales of goods, stationary periods of harvest and in the provision of services. These contracts can last no longer than 6 months and are renewable for no longer than other 6 months.

Finally, workers can be hired through associative employment cooperatives, generating contracts for which there are no mandatory non-wage labor costs. This type of contracts is also fixed-term.

In the paper, we focus on open-ended and fixed-term contracts, not discriminating across the different forms of fixed-term contracts.

4. Data construction

We exploit panel information form the Annual Manufacturing Survey (AMS) conducted by the national statistical agency, DANE.¹⁶ The period spans from 2000 to 2014. The AMS is a census that covers information for all manufacturing establishments with 10 or more workers¹⁷ on labor, capital, consumption of intermediate goods, production, exports, and department. The unit of observation is the plant. Particularly relevant for this study, it distinguishes between temporary and permanent contracts, as well as skilled¹⁸ and unskilled¹⁹ workers.

Initially, there are 12,434 plants (11,745 firms)²⁰ in the period 2000–14.

We follow four rules to create the sample: (1) drop observations in the top/bottom 1% of value added; (2) exclude observations that show more than 400% growth from 1 year to the other in the total labor variable, as it does not seem plausible; (3) exclude plants

¹⁶National Administrative Department of Statistics.

¹⁷If there is no information on employment, the variable discriminating participation in the census is yearly annual production above a certain threshold. From 2013 establishments with 5–10 people were included in the census, but we exclude them from the analysis for consistency.

¹⁸Professionals, technicians and production technologists, and administration and sales staff. For a more detailed description please refer to the Appendix.

¹⁹Production workers (i.e., workers dedicated to manufacturing, processing, assembling, maintenance, inspection, storage, packing, loading, etc.). For a more detailed description please refer to the Appendix.

²⁰97,312 observations with non-missing industry values and with more than 10 employees.

that consistently have fewer than 15 employees; and (4) drop firms from industries with too few observations (less than 70, i.e., tobacco and office & equipment).

Applying these rules, we are left with 10,750 plants (corresponding to 10,132 firms), for a total of 89,796 observations.

Since the estimation methodology we adopt requires the inclusion of variables up to their second-lag, we lose observations with missing values in the two lags of the variables of interest. Finally, when applying Levinsohn and Petrin (2003), we lose observations where electricity consumption is either missing or zero; while applying Olley and Pakes (1996) we also lose all the observations where investment is either missing or zero.

For the final sample used with Levinsohn and Petrin (2003) we are left with 8,430 plants (7,980 firms), corresponding to 57,967 observations. As expected, the final sample for the Olley and Pakes (1996) methodology is smaller: 6,997 plants (6,591 firms), corresponding to 37,222 observations. All the analysis is going to be at the plant level.

Further details about the sample construction and the definition of variables are presented in the Appendix.

5. Empirical strategy

Our empirical strategy adopts the theoretical model proposed by Addessi (2014), where different labor contracts are introduced. Empirically the model follows the Levinsohn and Petrin (2003) (here after LP) approach while also tackling the multicollinearity problem described in Ackerberg, Caves, and Frazer (2006) (henceforth AFC). The production function is a Cobb-Douglas and labor services are perfect substitutes that can be characterized by different labor-augmenting factors. The dynamics are introduced in the model by assuming that the TFP follows a controlled Markov chain process that can be influenced by the labor-contract choice with a time period lag. Our contribution is to explore the effects of labor contract choice on both the labor-augmenting and the TFPaugmenting in a context different from the advanced economies that have usually dominated the literature. Alternatively, we investigate the Olley and Pakes (1996) (hereafter OP) approach, taking in consideration the multicollinearity and endogenous problem observed in AFC, but our preferred approach is adopting LP as it offers two main advantages. First, the investment proxy is only valid for establishments that exhibit nonzero investments, which amounts to losing a great deal of data compared to using intermediate inputs as a proxy. Second, adjustment costs may lead to kink points in the investment demand function, i.e., plants will note fully respond to some productivity shocks, while adjustment of the intermediate inputs to the productivity shock may be entire, eliminating the correlation between the error term and the regressors.

5.1. OP and LP with the AFC interdependence problem correction

The Cobb-Douglas value added production function is:

$$Y_t = e^{\omega_t} K_t^{\beta_k} L_t^{\beta_l} \tag{2}$$

where Y_t is value added, e^{ω_t} is a technology factor, K_t is capital and L_t is labor.

The logarithmic form of the value-added production function is:

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$$y_t = \omega_t + \beta_k k_t + \beta_l l_t + \eta_t \tag{3}$$

where y_t and k_t are the log transformations of Y_t and K_t and η_t is an untransmitted shock. ω_t is unobserved productivity that enters in the firm's decision problem, while η_t is either measurement error or a shock to productivity which is not forecastable. The endogeneity arises because decisions on input choices are influenced by the firm's beliefs on ω_t , biasing upward OLS estimates of input coefficients, β_k and β_l

LP and OP propose alternatives to proxy productivity: LP intermediate goods (electricity, fuel, or materials), represented by m_t , and OP use investment expenditure, i_t . In this paper, we will use electricity consumption as m_t .

To allow the possibility that contracts induce a static difference in labor productivity, we follow Addessi (2014) and define labor as $(P_t + sT_t)$, where P_t are workers with permanent contracts and T_t temporary ones, and s > 0.

Hence, the logarithmic form of the value-added production function becomes:

$$y_t = \omega_t + \beta_k k_t + \beta_l ln(P + sT) + \eta_t \tag{4}$$

The other effect of labor contract choice is dynamic and affects TFP growth. Let us define $X_t = P_t/(P_t + T_t)$, and assume that TFP follows a first-order Markov process:

$$\omega_t = g(\omega_{t-1}) + \gamma X_{t-1} + \mu_t \tag{5}$$

where $\mu_t \sim N(0, \sigma_{\mu})$ and $g(\cdot)$ is a function relating TFP to its previous period.

If we totally differentiate (4) after plugging in (5), we have:

$$\frac{dY}{Y} = \beta_k \frac{dK}{K} + \beta_l \left[\frac{dP}{P} X_t + \frac{dT}{T} \left(1 - X_t \right) \left(\frac{sP + sT}{P + sT} \right) \right] + \frac{d(g(\omega_{t-1})) + \gamma dX_{t-1}}{\omega_t} \tag{6}$$

From Equation (6) we can see that *s* is a factor that changes the elasticity of production with respect to temporary workers and γ captures by how much factor-neutral productivity increases when the share of permanent workers increases by one unit.

The investment demand is presented by OP as a polynomial function of the unobserved productivity shock and capital. We follow Addessi to take into consideration the different labor contract types and define investment as a function of the different contract types, $i_t = f(\omega_t, x_t, p_t, k_t)$, where x_t and p_t are log transformations of X and P_t .²¹ The inclusion of x_t and P_t follows the intuition that investment is a forward looking variable and that the current level of x_t and P_t affects future TFP and consequently investment. Since under certain assumptions investment is strictly increasing in productivity, it is possible to invert it and define productivity as a function of observables, $\omega_t = f^{-1}(i_t, x_t, p_t, k_t)$.

LP adopts a similar approach, but use the demand of intermediate goods as a function of ω_t , hence in this case $\omega_t = f^{-1}(m_t, x_t, p_t, k_t)$.²²

Addessi's methodology requires a two-step procedure, each stage corresponding to a different moment condition. However, to have consistent estimates we also need to control for selection bias; hence, we follow OP (1996) and introduce a further step to estimate survival probabilities.

 $^{{}^{21}}t_t = f(\omega_t, x_t, p_t, k_t)$ is defined on permanent contracts and labor contract composition, not on temporary contracts. This is because once we control for x_t and P_t , we also control for T_t (Addessi, 2014).

²²In this case $m_t = f(\omega_t, x_t, p_t, k_t)$ is justified by the idea that the intermediate inputs are the last ones to be chosen, hence the demand for *m* depends on x_t, p_t, t_t . Controlling for x_t and P_t is equivalent to controlling for x_t, P_t, T_t .

First, we define $\phi_t = \omega_t + \beta_k k_t + \beta_l \ln(P + sT) = f^{-1}(i_t, x_t, p_t, k_t) + \beta_k k_t + \beta_l \ln(P + sT) = \phi_t(i_t, x_t, p_t, k_t)$ and substitute in the production function to obtain the first stages:

LP-ACF:
$$y_t = \boldsymbol{\phi}_t(m_t, x_t, p_t, k_t) + \eta_t$$
 (7)

OP-ACF:
$$y_t = \boldsymbol{\phi}_t(i_t, x_t, p_t, k_t) + \eta_t$$
 (8)

While in standard LP and OP, $\hat{\beta}_l$ would be identified in the first stage, according to ACF there are functional dependence problems that impede the estimation of input coefficients in the first step²³ (for details see Ackerberg et al., 2006).²⁴ Hence, in the first stage we run a non-parametric regression of y_t on $\phi_t(\cdot)$ and estimate $\hat{\phi}_t(\cdot) = y_t - \hat{\eta}_t$, but not yet $\hat{\beta}_l$.

In a *second stage* we estimate the probability of survival by fitting a probit model of a survival dummy on $m_{t-1}, x_{t-1}, p_{t-1}, k_{t-1}$. We call the predicted probabilities from this model $\hat{P}r_t$.

Input coefficients are estimated in the *third stage*. Since $\omega_t = E[\omega_t | \Omega_{t-1}] + \varepsilon_t = E[\omega_t | \omega_{t-1}, X_{t-1}] + \varepsilon_t = g(\omega_{t-1}) + \gamma X_{t-1} + \varepsilon_t$, where $\varepsilon_t \sim N(0, \sigma_{\varepsilon})$, the second stages of LP and OP are given by:

LP-AFC :

$$\hat{\phi}_{t} = \beta_{k}k_{t} + \beta_{l}\ln(P_{t} + sT_{t}) + g\left(\hat{\phi}_{t-1} - \beta_{k}k_{t-1} - \beta_{l}\ln(P_{t-1} + sT_{t-1}), \widehat{Pr}_{t}\right)$$
(9)
+ $\gamma X_{t-1} + \varepsilon_{t}$

OP-AFC:

$$\hat{\phi}_{t} = \beta_{k}k_{t} + \beta_{l}\ln(P_{t} + sT_{t}) + g\left(\hat{\phi}_{t-1} - \beta_{k}k_{t-1} - \beta_{l}\ln(P_{t-1} + sT_{t-1}), \widehat{Pr}_{t}\right)$$
(10)
+ $\gamma X_{t-1} + \varepsilon_{t}$

where $g(\cdot)$ is a non-linear function of the fourth order. We estimate the third stage by a nonlinear least squares regression rather than imposing generic orthogonality conditions between the residuals and the independent variables for two main reasons (reported also in Addessi, 2014). First, our procedure provides a precise identification for the functional form of the underlying production function. Second, the choice to impose orthogonality conditions between the residuals and, separately, the logarithm of *P* and of *T* would reduce the number of observations as the firms with no temporary workers would be missing from our estimations. Since labor contracts are chosen after the realization of the productivity shock ε_t , we instrument *P* and *T* with their lagged values, as in the ACF procedure. We refer to the procedures implementing the 2-steps of the structural model in Addessi (2014) as *Bench1* and *Bench2*. *Bench2* differs from *Bench1* in the fact that the labor-contract choice at *t*-1 is instrumented with its lag. In either case, the

 $^{^{23}\}hat{\beta}_l$ is well identified only under some specific conditions in the data-generating process.

²⁴AFC propose to invert conditional rather than unconditional input demand functions to control for unobserved productivity. Hence, the first stage moment condition is $E[\eta_t|\Omega_{t-1}] = E[y_t - \phi_t(\cdot)|\Omega_{t-1}] = 0$ rather than $E[\eta_t|\Omega_{t-1}] = E[y_t - \beta_t|_t - \phi_t(i_t, k_t)|\Omega_{t-1}] = 0$. As a consequence, β_t cannot be estimated.

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labor contract choice precedes the realization of the unexpected productivity shock ε_t , which allows us to estimate the impact of labor composition on productivity.

Since the predicted values have been used for ϕ_t , the standard errors need to be corrected by bootstrap.

To explore further the role of skills composition, we divide temporary and permanent workers into skilled and unskilled. Our third stages become:

$$\begin{aligned} \mathbf{LP} - \mathbf{AFC} : \qquad \boldsymbol{\phi}_{t} &= \beta_{k} k_{t} + \beta_{l} \ln(P_{s} k_{t} T_{s} k_{t} + s_{pu} P_{uns} k_{t} + s_{tu} T_{uns} k_{t}) \\ &+ g(\hat{\boldsymbol{\phi}}_{t-1} - \beta_{k} k_{t-1} - \beta_{l} \ln(P_{s} k_{t-1} + s_{ts} T_{s} k_{t-1} \\ &+ s_{pu} P_{uns} k_{t-1} + s_{tu} T_{uns} k_{t-1}), \widehat{Pr}_{t}) \\ &+ \gamma_{s} X_{s} k_{t-1} + \gamma_{u} X_{uns} k_{t-1} + \varepsilon_{t} \end{aligned}$$
(11)

$$\mathbf{OP}-\mathbf{AFC}: \qquad \hat{\boldsymbol{\phi}}_{t} = \beta_{k}k_{t} + \beta_{l}\ln(P_sk_{t} + s_{ts}T_sk_{t} + s_{pu}P_unsk_{t} + s_{tu}T_unsk_{t}) + g(\hat{\boldsymbol{\phi}}_{t-1} - \beta_{k}k_{t-1} - \beta_{l}\ln(P_sk_{t-1} + s_{ts}T_sk_{t-1} + s_{pu}P_unsk_{t-1} + s_{tu}T_unsk_{t-1}), \widehat{Pr_{t}}) + \gamma_{v}X_sk_{t-1} + \gamma_{v}X_unsk_{t-1} + \varepsilon_{t}$$

$$(12)$$

where P_{sk} (T_{sk}) are the skilled workers with permanent (temporary) contracts, and P_{unsk} (T_{unsk}) the unskilled workers with permanent (temporary) contracts; X_{sk} (X_{sunk}) is the share of skilled (unskilled) workers with permanent contracts within the skilled (unskilled).

6. Results

Tables 2–5 show the estimated β_k , β_l , s, and γ from Equation (8). s and γ are the parameters of most interest in this paper. s is a factor that reduces the elasticity of production with respect to temporary workers: if s < 1, the elasticity of value added with respect to temporary workers is lower than that with respect to permanent workers;²⁵ if s > 1, the elasticity of value added with respect to temporary workers is larger. The results help understand how the composition of permanent and temporary workers affects productivity, defined as value added per worker. γ captures by how much factor-neutral productivity increases when the share of permanent workers increases by one unit.

The OLS estimation is a standard ordinary least square regression which ignores three main elements: (i) input services are correlated with the unobserved productivity, (ii) labor services are not homogenous, and (iii) productivity follows a Markov process; hence, s = 1, while $g(\cdot)$ and γ are not estimated. The estimation called 2-steps applies the procedure previously exposed except for considering productivity as an exogenous Markov process (i.e., not including labor-service composition, X, in TFP); it includes estimation of $g(\cdot)$. *Bench1* and *Bench2* are consistent with the procedure and the hypotheses presented in the previous section. They differ in the time reference of X. In

 $^{^{25}}$ s is the labor-augmenting factor of temporary contracts. If s = 1, the elasticity of value added with respect to temporary contracts and permanent contracts are the same; this translates into an equal contribution to labor productivity, defined as value added per worker.

		Panel A.	Aggregate			Panel B.	Small Size	
	OLS	2 steps	Bench 1	Bench 2	OLS	2 steps	Bench 1	Bench 2
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
β _k	0.308***	0.085***	0.085***	0.085***	0.276***	0.092***	0.091***	0.092***
•	(0.007)	(0.005)	(0.005)	(0.005)	(0.008)	(0.006)	(0.006)	(0.006)
β _I	0.831***	0.986***	0.986***	0.986***	0.8/3***	0.98/***	0.989***	0.988***
	(0.011)	(0.009)	(0.009)	(0.009)	(0.020)	(0.009)	(0.010)	(0.010)
S		0.831***	0.832***	0.831***		0.941***	0.945***	0.941***
		(0.012)	(0.012)	(0.012)		(0.016)	(0.016)	(0.016)
γ			-0.00/**	0.001			-0.020***	-0.008**
ol .:	57.047	57.047	(0.003)	(0.002)	20 554	20 554	(0.004)	(0.004)
Observations	57,967	57,967	57,967	57,967	29,551	29,551	29,551	29,551
		Panel C. M	edium Size			Panel D.	Large Size	
	OLS	2 steps	Bench 1	Bench 2	OLS	2 steps	Bench 1	Bench 2
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
βı	0.326***	0.081***	0.081***	0.081***	0.370***	0.081***	0.080***	0.081***
FK	(0.008)	(0.007)	(0.007)	(0.007)	(0.015)	(0.011)	(0.011)	(0.011)
ßı	0.860***	1.008***	1.006***	1.006***	0.519***	0.926***	0.923***	0.924***
r i	(0.027)	(0.012)	(0.012)	(0.012)	(0.057)	(0.023)	(0.023)	(0.023)
S	. ,	0.776***	0.775***	0.777***	. ,	0.503***	0.495***	0.505***
		(0.016)	(0.015)	(0.016)		(0.039)	(0.037)	(0.038)
γ			0.011*	0.013**			0.055***	0.055***
			(0.007)	(0.006)			(0.010)	(0.009)
Observations	21,235	21,235	21,235	21,235	7,181	7,181	7,181	7,181

Table 2. Results in the aggregate and by plant size.

Notes: Bootstrapped standard errors in parentheses ***p < 0.01, **p < 0.05, *p < 0.1

Table 3.	Results	by	exporting	status	of the plant
			- I - J		

		Panel A. N	o exporter			Panel B. Exporter		
	OLS	2 steps	Bench 1	Bench 2	OLS	2 steps	Bench 1	Bench 2
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
β _k	0.283***	0.088***	0.088***	0.088***	0.369***	0.073***	0.074***	0.073***
	(0.007)	(0.005)	(0.005)	(0.005)	(0.011)	(0.008)	(0.008)	(0.008)
βι	0.869***	0.973***	0.973***	0.973***	0.651***	1.011***	1.011***	1.011***
	(0.012)	(0.008)	(0.008)	(0.008)	(0.024)	(0.016)	(0.016)	(0.016)
S		0.861***	0.861***	0.861***		0.718***	0.715***	0.718***
		(0.013)	(0.013)	(0.013)		(0.023)	(0.023)	(0.023)
γ			-0.007**	0.003			0.015**	0.008
			(0.003)	(0.003)			(0.006)	(0.007)
Observations	45,567	45,567	45,567	45,567	12,400	12,400	12,400	12,400

Notes: Bootstrapped standard errors in parentheses ***p < 0.01, **p < 0.05, *p < 0.1

Table 4. Results by area.

		Panel A. M	ore densely			Panel B. Less densely		
	OLS	2 steps	Bench 1	Bench 2	OLS	2 steps	Bench 1	Bench 2
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
β _k	0.263*** (0.007)	0.083*** (0.005)	0.083*** (0.005)	0.083*** (0.005)	0.362*** (0.011)	0.091*** (0.007)	0.091*** (0.007)	0.091*** (0.007)
βι	0.883*** (0.014)	0.983*** (0.010)	0.983*** (0.010)	0.983*** (0.010)	0.769*** (0.023)	0.996*** (0.013)	0.996*** (0.013)	0.996*** (0.013)
S		0.853*** (0.017)	0.853*** (0.016)	0.853*** (0.017)		0.786*** (0.024)	0.786*** (0.023)	0.787*** (0.024)
γ			-0.001 (0.003)	0.004 (0.003)			-0.003 (0.007)	0.009* (0.005)
Observations	40,365	40,365	40,365	40,365	17,602	17,602	17,602	17,602

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	F	Panel A. Aggregat	e	F	anel B. Small Size	e
	2 steps	Bench 1	Bench 2	2 steps	Bench 1	Bench 2
	(1)	(2)	(3)	(1)	(2)	(3)
$\beta_{perm,sk}$	0.986*** (0.009)	0.986*** (0.009)	0.986*** (0.009)	0.987*** (0.010)	0.989*** (0.010)	0.989*** (0.010)
S _{temp,sk}	0.760*** (0.022)	0.754*** (0.021)	0.758*** (0.022)	0.918*** (0.028)	0.911*** (0.028)	0.917*** (0.028)
S _{perm,unsk}	0.914***	0.907***	0.917***	0.942***	0.936***	0.947***
S _{temp,unsk}	0.788*** (0.018)	0.786*** (0.018)	0.790*** (0.018)	0.898*** (0.027)	0.896*** (0.026)	0.901*** (0.026)
Yskilled		1.601 (2.086)	0.032*** (0.008)		1.251 (2.181)	0.031*** (0.006)
Yunskilled		1.19 (2.086)	0.004 (0.008)		1.211 (2.180)	-0.005 (0.007)
Observations	57,967	57,967	57,967	29,551	29,551	29,551
	Pa	anel C. Medium Si	ze	F	anel D. Large Siz	e
	2 steps	Bench 1	Bench 2	2 steps	Bench 1	Bench 2
	(1)	(2)	(3)	(1)	(2)	(3)
$\beta_{\text{perm,sk}}$	1.009*** (0.012)	1.010*** (0.012)	1.009*** (0.012)	0.926*** (0.023)	0.926*** (0.023)	0.926*** (0.023)
S _{temp,sk}	0.669*** (0.033)	0.666*** (0.033)	0.668*** (0.032)	0.486*** (0.056)	0.483*** (0.056)	0.485*** (0.056)
S _{perm,unsk}	0.868*** (0.031)	0.863*** (0.030)	0.869*** (0.031)	0.978*** (0.088)	0.972*** (0.087)	0.978*** (0.089)
S _{temp,unsk}	0.720*** (0.029)	0.719*** (0.029)	0.721*** (0.029)	0.499*** (0.055)	0.498*** (0.054)	0.499*** (0.055)
Yskilled	(=)	1.653	0.039*** (0.014)	(2.55	0.007
Yunskilled		1.654	0.024 (0.015)		2.532	0.002
Observations	21,235	21,235	21,235	7,181	7,181	7,181

Table	Results	on skilled	d vs unskille	d in the	aggregate	and k	oy p	lant size.

Notes: Bootstrapped standard errors in parentheses, ***p < 0.01, **p < 0.05, *p < 0.1

Bench1, *X* is not instrumented since there is no reason to expect correlation between the composition of the labor contracts at time *t*-1 and the productivity shock at time *t*, while in *Bench2 X* is instrumented with its lagged value.

Table 2 shows the results for the entire sample and by plant size. Table 3 divides plants between exporters and non-exporters, while Table 4 presents the results by geographical area.

As we can see in column (1) of Panel A (Table 2), when estimating an OLS regression in the manufacturing sample, the elasticities of value added with respect to capital and labor services, β_k and β_l , are 0.308 and 0.831.

Moving beyond the OLS procedure, we need to guess an initial value for the parameters to be estimated; our guess is 0.4 for β_k , 0.6 for β_l , 1 for *s* (i.e., temporary and permanent contracts are characterized by the same labor-augmenting factor) and 0 for γ (i.e., labor-contract composition has no effect on the dynamic generation process of TFP).

When we split labor into temporary and permanent workers and run the 2-steps estimation (column 2), β_k and β_l are 0.085 (s.e. 0.005) and 0.986 (s.e. 0.009), while s is

0.831 (s.e. 0.012), significantly different from 1, suggesting that labor contracts induce a static difference in labor productivity.

Unlike in Addessi (2014), introducing the labor-contract composition in the TFP dynamics does not change the estimated coefficients in our setting. When we estimate the model through *Bench1*, we find that s is 0.832 (s.e. 0.012), significant at 1% level (column 3). The finding is confirmed under Bench2 estimation (column 4).²⁶ This means that the elasticity of production to temporary workers is lower than that of permanent workers. The estimated y according to the *Bench1* estimation is -0.007 (s.e. 0.003), significantly different from zero at 5% level, but according to Bench2 it is not significantly different from zero. This signals that the share of permanent workers in a plant has a negative effect on TFP with a lag, if any. An analysis of the heterogenous effects by size presented in Panels B-D of Table 2 sheds some light on these results. First, we find that the larger the plant, the lower the parameter s. While the elasticity of revenue with respect to temporary workers in small plants is just slightly smaller than that of permanent workers (s is just a bit smaller 1, but the difference is significant), in mediumsize plants it is lower than that of permanent workers, and even lower in large plants. According to Bench1 estimations (column 3, Panel B, Table 2), s is 0.945 (s.e. 0.016), 0.775 (s.e. 0.015) and 0.495 (s.e. 0.037) for small, medium, and large companies, respectively. The coefficient y indicates that the incidence of permanent contracts in total contracts has a negative effect on TFP with a lag in small size firms, but a positive effect in larger firms. We have shown in the previous section that plants hire sizable proportions of temporary workers, and this seems to affect negatively both production and TFP with a lag, except for small firms, where there seems to be a positive effect of flexibility. This result is in line with the idea that the flexibility of temporary contracts may lead to within-firm productivity gains in firms with low sophistication, which may well be proxied for by a small size.

In the case of both exporters and non-exporters, the elasticity of revenue with respect to temporary workers is lower than that of permanent workers, with the gap being larger in exporting plants (Table 3): according to *Bench1* model, the estimation of *s* is 0.861 (s.e. 0.013) for non-exporters and 0.715 (s.e. 0.023) for exporters. In TFP dynamics we do not observe an effect from a higher share of permanent contracts in exporters. As for non-exporters, an increase of one unit in the share of permanent contracts might have a negative effect on TFP with a lag, but the result is not very robust.

We also examine whether temporary workers are characterized by a different level of productivity depending on the geographical area where plants operate. To do so, we divide the sample into two groups: plants operating in the most populous departments, where we assume greater possibilities of networking among plants (Bogota D.C, Antioquia and Valle del Cauca), and plants operating in the remaining ones. In both areas, the elasticity of value added with respect to temporary workers is lower than that of permanent workers: *s* is 0.934 (s.e. 0.021) in the most densely populated areas and 0.872 (s.e. 0.010) in the remaining areas (Table 4); γ is not significantly different from zero for more densely populated areas (-0.001, s.e. 0.003) and negative for less densely populated ones (-0.004, s.e. 0.002). However, the estimated coefficient for less densely populated

²⁶According to *Bench2* estimates, s is 0.831 (s.e. 0.012).

areas is only marginally significant and the finding is not very robust to using a different approach (i.e., *Bench2*).

Overall, it seems that the elasticity of revenue with respect to temporary workers is lower (or in the best-case scenario not significantly different) compared to that of permanent workers. To assess whether this result is driven by the lower shares of skilled workers among the temporary, we estimate Equation (11). Results are presented in Table 5.

In the aggregate manufacturing sector, we find that the elasticity of revenue of permanent unskilled workers is slightly lower than that of permanent skilled workers ($s_{perm,unsk} = 0.907$, s.e. 0.016), but it is mainly the elasticity of skilled and unskilled temporary workers that is much lower than that of permanent workers ($s_{temp,sk} = 0.754$, s.e. 0.021; $s_{temp,unsk} = 0.786$, s.e. 0.018).

Let us recall that we found that temporary workers are almost as productive as permanent workers in small plants. When we disentangle workers by skill levels too, we find that unskilled workers with temporary or permanent contracts are equally productive: $s_{perm,unsk}$ is 0.936 (s.e. 0.020), and $s_{temp,unsk}$ is 0.896 (s.e. 0.026), even though both of the estimated parameters are significantly different from 1. $s_{temp,sk}$ is 0.911 (s.e. 0.028), which is also significantly different from 1,²⁷ suggesting that within skilled workers in small plants temporary contracts can be detrimental. However, the majority of workers in small plants are unskilled, so the latter does not have much weight overall. In medium and large plants, we find that temporary workers increase value added to an even lower extent than permanent: $s_{temp,sk} = 0.666$, s.e. 0.033; $s_{temp,unsk} = 0.719$, s.e. 0.029 in medium firms and $s_{temp,sk} = 0.483$, s.e. 0.056; $s_{temp,unsk} = 0.498$, s.e. 0.054 in large firms. In sum, in medium and large firms the elasticity of value added of temporary workers, either skilled or unskilled, is always lower than that of permanent workers. In a nutshell, when the elasticity of value added of temporary workers, either skilled or unskilled, is not driven by their skill composition.²⁸

Finally, when we allow the production function to differ across subsectors (Tables A1–A3), estimations differ depending on the methodology adopted (LP/OP), which makes it hard to draw robust conclusions.

6.1. Robustness checks

First, it is reassuring to note that *Bench1* and *Bench2* estimates are almost identical. Our estimates are robust to changing the degree of the polynomial used in the estimation of the first and third steps, to changing the propensity score, to calculating the first stage distinguishing by skills, to changing the number of replications used for bootstrapping errors, to using consumption of all intermediate good rather than electricity only, to varying the initial parameters' values assigned in non-linear squares estimations.

The same applies for the estimate of the *s* and γ parameters when we re-conduct all the analysis through OP (Tables A4–A6). Only the findings across subsectors are not robust, hence we do not rely on them.

²⁷The p-value of the difference between s_{ts} and 1 is 0.051.

 $^{^{28}\}gamma_{skilled}$ is sometimes significantly different from zero, but the estimates are not very robust.

7. Conclusion

The rise in temporary contracts in Colombia raises questions on its consequences on firm productivity. To estimate the effects of hiring workers through temporary rather than open-ended contracts, we follow Addessi (2014) and apply a Levinsohn and Petrin (2003) structural model in three steps, including the Ackerberg et al. (2016) correction and endogenizing TFP. We also use the Olley and Pakes (1996) approach. We find that in general the elasticity of value added with respect to temporary workers in the manufacturing sector in 2000-14 is lower than that of permanent workers. However, when exploring the effects of the contract mix on TFP dynamics, we find that a higher share of permanent contracts can have a negative influence on TFP with a lag. Analyzing results by size sheds some light: while in larger firms the elasticity of value added is larger for permanent workers, who also seem to have a positive effect on TFP with a lag, this is not true for small firms, which represent the most numerous group of firms in our setting. One possibility might be that for small firm some flexible forms of hiring can be important. Results also present some heterogeneity by exporting status or geographical area. We analyze whether the lower productivity of fixed-term contracts is driven by a higher proportion of unskilled workers holding those contracts and do not find support for this thesis as results seem to be driven mostly by the contract type itself.

Even though we are unable to measure the temporary-to-permanent conversion rate, the large share of temporary workers that prevails in Colombia might suggest that temporary contracts are a dead-end cost-reduction device rather than a steppingstone for workers to become permanent. This can have some negative effects on productivity, depending on firm characteristics. In the OECD, there have been proposals to replace dual labor markets with a single open-ended contract,²⁹ where termination costs that increase smoothly with job tenure allow the gains of both fixed-term and permanent contracts (Bentolila, Boeri, & Cahuc, 2012; Blanchard & Tirole, 2003; Boeri & Garibaldi, 2008; Cahuc, 2012; Dolado, 2012; IMF, 2014, 2015, 2017; OECD, 2014). Due to the low degree of employment protection in the initial period, this instrument can be used as a screening device, but as employment protection becomes more stringent with job tenure, it also serves as an incentive for plants to invest in training for all workers and search for the right matches. Given the similar EPL that characterizes Colombia, this single open-ended contract could be a tool to fight a segmented labor market that in some cases can slow productivity down. At the same time, fixed-term contracts should not be eliminated, which might have other unintended consequences, as flexible forms of contract can also allow less employable people to be employed more easily, and allow a flexible flow of resources from low productivity uses to high productivity ones.

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²⁹In Spain, Italy, and France.

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us with the access to the data. The content and findings of this paper reflect the opinions of the authors and not those of the Inter-American Development Bank. Corresponding author: Giulia Lotti (email: glotti@iadb.org).

Disclosure statement

No potential conflict of interest was reported by the authors.

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Appendix A. Data and definition of variables

A. Sample Selection

Initially, there are 12,434 plants (11,745 firms), corresponding to 97,312 observations with nonmissing industry values and with more than 10 employees in the period 2000–14.

First, we drop observations in the top/bottom 1% of value added; and we are left with 12,359 plants (11,681 firms) and 95,388 observations.

We also exclude observations that show more than 400% growth from 1 year to the other in the total labor variable, as this level of growth in employment does not seem plausible: we are left with 12,359 plants (corresponding to the same number of firms, and 94,746 observations).

Following Eslava et al. (2014), we also drop plants that consistently have fewer than 15 employees: we are left with 10,761 plants (10,142 firms), corresponding to 89,859 observations.

We remove firms from industries with too few observations (less than 70): tobacco (28 observations) and office & equipment (35 observations); we are left with 10,750 plants (10,132 firms) and 89,796 observations.

Since in *Bench2* estimations we need to include variables up to their second-lag and since we prefer to use the same sample for all estimations (OLS, 2-steps, *Bench1*, *Bench2*) to obtain comparable results, we need to drop observations that do not have up to two lags in the variables of interest. Hence, we lose observations in the first two years of the sample: our regression will relate to the period 2002–2014. We also lose observations for firms with missing values in the two previous lags in any of the variables entering the regressions.

Finally, when applying OP we also lose all the observations in which investment is either missing or zero; while applying LP we lose observations in which consumption of electricity is either missing or zero.

For OP we are left with 6,997 plants (6,591 firms), corresponding to 37,222 observations. The sample when running LP estimates is larger: 8,430 plants (7,980 firms), corresponding to 57,967 observations.

B. Variable Definitions

Value Added: it is the total revenue received from the use of inputs (land, capital, labor, business organization) involved in the production function. The DANE calculates the value added as the difference between gross output and intermediate consumption.

Gross Output: the value of gross output is equal to the "Value of all the establishment's manufactured goods", plus the "Revenues from industrial subcontracting made for others", plus the "Value of the electric energy sold", plus the value of the revenue from CERT,³⁰ plus the "Value of stocks of the products in the manufacturing process at the start of the year", minus the "Value of the products in the manufacturing process at the end of the year", plus the value of other operating revenues, such as those generated by rent of goods produced and the installation, maintenance and repair of products manufactured by the establishment.

Capital: book value of fixed assets; it corresponds to all the fixed assets of the establishment, defined as those relatively durable goods not to be sold, for the use of the establishment and the development of its industrial activity; it includes all the physical assets that are expected to have a productive life longer than 1 year, and all those extensions, additions or improvements and major reforms that extend the life or normal economic efficiency of the assets (land, buildings, machinery and equipment, ongoing construction, office equipment, etc.).

Gross Investment: includes the sum of the investments in new and used fixed assets, manufactured for their own use or received in transfer from other establishments, less sales, withdrawals, and transfers of fixed assets owned by the plant.

³⁰Discounts caused during the year by exports of products y and subproducts prepared by the establishment.

Energy Consumption: value of electric power purchased (only the one attributable to the manufacturing process); it corresponds to the value in kwh. acquired by the establishment for its operation.

Permanent Personnel: corresponds to the yearly average of payroll personnel or plant personnel with a direct labor link with the establishment through an indefinite term contract.

Temporary Personnel: temporary staff hired directly by the establishment (corresponds to the yearly average staff hired through fixed-term contract to accomplish specific tasks under an agreed remuneration), and temporary staff hired by companies specialized in the supply of personnel (corresponds to yearly average staff without either a labor or contractual relationship with the plant, hired through agencies specialized in the supply of personnel to carry out specific tasks in the industrial establishment).

Skilled personnel: professionals, technicians, and production technologists (national and foreign; it refers to persons directly linked to productive activities or tasks directly related with production; this category includes mechanical, chemical, industrial, electrical, mining, and oil engineers, etc., and technicians and technologists who work directly in the production process), and administration and sales staff (the people who lead the economic, financial, and administrative aspects of the establishment and responsible for the elaboration and conduction of the general policy of the company, as managers, sub-managers, and paid directors; this includes: heads of the administrative staff, supervisors, security guards, staff that do not work in the area of production, vendors, distributors and/or delivery agents, if their remuneration is borne by the establishment; it does not include warehouse staff, administrative offices, management, warehouses and other auxiliary units not directly linked to the establishment or located in a place different from the productive plant).

Unskilled personnel: production workers (it corresponds to workers dedicated to manufacturing, processing, assembling, maintenance, inspection, storage, packing, loading such as: internal delivery couriers, chauffeurs, cleaning machines personnel, supervisors, and foremen who work manually, drivers of vehicles for transport of raw materials, materials or products only within the establishment, workers dedicated to maintenance and repair (mechanical, electrical, etc.) of the machinery and industrial equipment; administrative supervisors, supervisors dedicated mainly to the supervision of the workers, surveillance personnel, guards, staff working in production area).

Deflators: variables are adjusted with the producer price index (PPI) for each two-digit ISIC (International Standard Industrial Classification of All Economic Activities) sector; December values are taken for each year; base period December 2014 = 100. As PPI is at the sector level (not plant level), what we measure is TFPR ("revenue" productivity).

Exporters: firms that sell at least 10% of their total sales abroad.

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	Panel A	. Food & Be	everages		Panel B. Woo	od	Pa	inel C. Texti	les
	2 steps	Bench 1	Bench 2	2 steps	Bench 1	Bench 2	2 steps	Bench 1	Bench 2
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
β _k	0.134***	0.134***	0.134***	0.057	0.055	0.054	0.066***	0.064***	0.065***
	(0.005)	(0.005)	(0.005)	(0.059)	(0.061)	(0.061)	(0.013)	(0.013)	(0.013)
βι	0.915***	0.915***	0.915***	1.098***	1.097***	1.099***	0.933***	0.930***	0.932***
	(0.017)	(0.017)	(0.017)	(0.066)	(0.066)	(0.066)	(0.024)	(0.024)	(0.024)
s	1.122***	1.124***	1.122***	0.958***	0.954***	0.949***	0.830***	0.825***	0.826***
	(0.042)	(0.042)	(0.042)	(0.158)	(0.158)	(0.155)	(0.031)	(0.033)	(0.032)
γ		-0.009	0.002		-0.031	-0.041		-0.018	-0.011
		(0.006)	(0.006)		(0.054)	(0.034)		(0.012)	(0.010)
Observations	11,740	11,740	11,740	866	866	866	2,607	2,607	2,607
	Ра	nel D. Appa	arel	P	anel E. Leath	ner	Р	anel F. Pap	er
	2 steps	Bench 1	Bench 2	2 steps	Bench 1	Bench 2	2 steps	Bench 1	Bench 2
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
β _k	0.090***	0.089***	0.089***	0.053***	0.049***	0.050***	0.137***	0.140***	0.139***
	(0.010)	(0.010)	(0.010)	(0.015)	(0.015)	(0.015)	(0.029)	(0.029)	(0.029)
βι	0.834***	0.833***	0.833***	1.035***	1.026***	1.028***	1.029***	1.031***	1.031***
	(0.014)	(0.013)	(0.013)	(0.019)	(0.018)	(0.018)	(0.050)	(0.048)	(0.049)
S	0.787***	0.786***	0.785***	1.140***	1.134***	1.127***	0.722***	0.725***	0.722***
	(0.022)	(0.023)	(0.023)	(0.050)	(0.049)	(0.049)	(0.050)	(0.050)	(0.050)
γ		-0.014*	-0.014**		-0.059***	-0.050***		-0.034*	-0.028
		(0.009)	(0.007)		(0.012)	(0.013)		(0.020)	(0.020)
Observations	4,830	4,830	4,830	1,753	1,753	1,753	1,493	1,493	1,493
	Pa	nel G. Print	ing	Pa	nel H. Petrol	eum	Par	nel I. Chemi	cals
	2 steps	Bench 1	Bench 2	2 steps	Bench 1	Bench 2	2 steps	Bench 1	Bench 2
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
β _k	0.137***	0.137***	0.137***	0.253*	0.246	0.225	0.101***	0.101***	0.101***
	(0.010)	(0.010)	(0.010)	(0.148)	(0.152)	(0.175)	(0.012)	(0.012)	(0.012)
βι	1.042***	1.041***	1.042***	0.357***	0.339**	0.342**	0.913***	0.912***	0.913***
	(0.019)	(0.019)	(0.019)	(0.130)	(0.132)	(0.143)	(0.027)	(0.027)	(0.027)
S	0.761***	0.758***	0.762***	0.082	0.101	0.072	0.664***	0.667***	0.664***
	(0.029)	(0.031)	(0.031)	(1.668)	(1.857)	(4.445)	(0.033)	(0.033)	(0.033)
γ		-0.010	0.001		-0.251	-0.419**		-0.017**	-0.009
		(0.013)	(0.010)		(0.242)	(0.200)		(0.008)	(0.009)
Observations	3,344	3,344	3,344	242	242	242	5,497	5,497	5,497

Table A1. Results by industrial subsector (LP-ACF).

	Panel	J. Rubber &	Plastic	Pa	anel K. Mine	rals	Pane	el L. Basic N	letals
	2 steps	Bench 1	Bench 2	2 steps	Bench 1	Bench 2	2 steps	Bench 1	Bench 2
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
β _k	0.078***	0.077***	0.078***	0.094***	0.094***	0.094***	0.079**	0.073**	0.074**
	(0.012)	(0.012)	(0.012)	(0.014)	(0.014)	(0.014)	(0.036)	(0.036)	(0.036)
βι	0.942***	0.942***	0.942***	1.123***	1.122***	1.123***	1.125***	1.123***	1.122***
	(0.024)	(0.024)	(0.024)	(0.037)	(0.036)	(0.037)	(0.036)	(0.036)	(0.036)
S	0.782***	0.782***	0.783***	0.770***	0.769***	0.770***	0.757***	0.748***	0.743***
	(0.026)	(0.026)	(0.026)	(0.063)	(0.064)	(0.065)	(0.050)	(0.056)	(0.055)
γ		-0.002	0.006		-0.019	-0.002		-0.034	-0.040
		(0.008)	(0.008)		(0.025)	(0.020)		(0.034)	(0.026)
Observations	4,965	4,965	4,965	3,539	3,539	3,539	1,108	1,108	1,108
	Р	anel M. Met	al	Par	nel N. Equipr	nent	Panel O.	Electronic M	Machinery
	2 steps	Bench 1	Bench 2	2 steps	Bench 1	Bench 2	2 steps	Bench 1	Bench 2
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
β_k	0.140***	0.137***	0.139***	0.017	0.014	0.015	0.067***	0.068***	0.067***
	(0.014)	(0.014)	(0.014)	(0.012)	(0.012)	(0.012)	(0.013)	(0.013)	(0.013)
βι	0.946***	0.943***	0.946***	1.065***	1.059***	1.060***	1.106***	1.107***	1.107***
	(0.020)	(0.020)	(0.020)	(0.017)	(0.017)	(0.017)	(0.046)	(0.046)	(0.046)
S	0.820***	0.814***	0.818***	0.825***	0.819***	0.812***	1.125***	1.127***	1.131***
	(0.034)	(0.033)	(0.034)	(0.032)	(0.033)	(0.033)	(0.104)	(0.106)	(0.108)
γ		-0.039***	-0.009		-0.057***	-0.054***		0.025	0.023
		(0.013)	(0.011)		(0.020)	(0.013)		(0.033)	(0.030)
Observations	3,656	3,656	3,656	3,144	3,144	3,144	1,091	1,091	1,091
	Panel	P. Medic. In	strum.	P	anel Q. Vehio	les	Panel	R. Otrher T	ransp.
	2 steps	Bench 1	Bench 2	2 steps	Bench 1	Bench 2	2 steps	Bench 1	Bench 2
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
β _k	-0.027	-0.026	-0.027	0.072***	0.067***	0.071***	0.075	0.075	0.067
	(0.035)	(0.037)	(0.036)	(0.018)	(0.018)	(0.018)	(0.135)	(0.135)	(0.136)
βι	1.074***	1.075***	1.074***	1.059***	1.055***	1.058***	1.279***	1.274***	1.277***
	(0.049)	(0.050)	(0.049)	(0.036)	(0.037)	(0.036)	(0.099)	(0.101)	(0.100)
s	0.739***	0.739***	0.739***	1.050***	1.042***	1.047***	0.721***	0.723***	0.704***
	(0.103)	(0.103)	(0.102)	(0.045)	(0.048)	(0.046)	(0.080)	(0.084)	(0.082)
γ		0.012	-0.002		-0.055**	-0.014		-0.059	-0.143
		(0.054)	(0.051)		(0.024)	(0.020)		(0.093)	(0.089)
Observations	411	411	411	1,284	1,284	1,284	330	330	330

Table A1. Results by industrial subsector (LP-ACF – continuation).

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		Panel S. Furniture	
	2 steps	Bench 1	Bench 2
	(1)	(2)	(3)
β _k	0.132***	0.129***	0.131***
	(0.011)	(0.011)	(0.011)
βι	1.053***	1.049***	1.052***
	(0.018)	(0.018)	(0.018)
S	0.702***	0.702***	0.702***
	(0.028)	(0.027)	(0.028)
γ		-0.027***	-0.005
		(0.010)	(0.009)
Observations	5,951	5,951	5,951

Table A1. Results by industrial subsector (LP-ACF – continuation).

Notes: Bootstrapped standard errors in parentheses, ***p < 0.01, **p < 0.05, *p < 0.1

Table A2. Results in the aggregate and by plant size (OP-ACF).

	Panel A. Aggregate				Panel B. Small Size			
	OLS	2 steps	Bench 1	Bench 2	OLS	2 steps	Bench 1	Bench 2
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
β _k	0.339***	0.159***	0.160***	0.160***	0.316***	0.169***	0.169***	0.169***
	(0.007)	(0.006)	(0.006)	(0.006)	(0.013)	(0.009)	(0.009)	(0.009)
βι	0.752***	0.928***	0.930***	0.929***	0.730***	0.878***	0.876***	0.876***
	(0.013)	(0.009)	(0.009)	(0.009)	(0.030)	(0.014)	(0.014)	(0.014)
S		0.830***	0.830***	0.834***		0.991***	0.992***	0.995***
		(0.015)	(0.015)	(0.016)		(0.025)	(0.025)	(0.025)
γ			0.018***	0.020***			0.010	0.011*
			(0.005)	(0.004)			(0.006)	(0.006)
Observations	37,222	37,222	37,222	37,222	15,535	15,535	15,535	15,535
R-squared	0.712	0.960	0.960	0.960	0.338	0.875	0.875	0.875
		Panel C. M	edium Size		Panel D. Large Size			
	OLS	2 steps	Bench 1	Bench 2	OLS	2 steps	Bench 1	Bench 2
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
β _k	0.340***	0.147***	0.147***	0.146***	0.383***	0.154***	0.151***	0.154***
	(0.009)	(0.010)	(0.011)	(0.010)	(0.013)	(0.015)	(0.014)	(0.014)
βι	0.809***	0.934***	0.928***	0.930***	0.552***	0.857***	0.853***	0.854***
	(0.028)	(0.011)	(0.011)	(0.011)	(0.045)	(0.021)	(0.021)	(0.021)
S		0.784***	0.785***	0.792***		0.487***	0.477***	0.495***
		(0.024)	(0.025)	(0.025)		(0.035)	(0.034)	(0.034)
γ			0.047***	0.041***			0.108***	0.095***
			(0.006)	(0.007)			(0.015)	(0.013)
Observations	15,824	15,824	15,824	15,824	5,863	5,863	5,863	5,863

	Panel A. No exporter				Panel B. Exporter			
	OLS	2 steps	Bench 1	Bench 2	OLS	2 steps	Bench 1	Bench 2
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
β _k	0.319***	0.167***	0.167***	0.167***	0.370***	0.134***	0.135***	0.135***
	(0.008)	(0.007)	(0.007)	(0.007)	(0.010)	(0.014)	(0.014)	(0.014)
βι	0.783***	0.919***	0.919***	0.919***	0.615***	0.937***	0.940***	0.939***
	(0.013)	(0.009)	(0.009)	(0.009)	(0.021)	(0.017)	(0.017)	(0.017)
S		0.864***	0.866***	0.869***		0.723***	0.715***	0.725***
		(0.017)	(0.016)	(0.017)		(0.032)	(0.032)	(0.032)
γ			0.012**	0.017***			0.048***	0.033***
			(0.005)	(0.004)			(0.009)	(0.007)
Observations	28,223	28,223	28,223	28,223	8,999	8,999	8,999	8,999

Table A3. Results by exporter (OP-ACF).

Notes: Bootstrapped standard errors in parentheses, ***p < 0.01, **p < 0.05, *p < 0.1

Table A4. Results by area (OP).

		Panel A. More densely				Panel B. Less densely			
	OLS	2 steps	Bench 1	Bench 2	OLS	2 steps	Bench 1	Bench 2	
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	
β _k	0.291***	0.133***	0.134***	0.134***	0.393***	0.200***	0.201***	0.201***	
	(0.010)	(0.008)	(0.008)	(0.008)	(0.012)	(0.011)	(0.011)	(0.011)	
βı	0.807***	0.947***	0.948***	0.948***	0.693***	0.909***	0.912***	0.911***	
	(0.014)	(0.010)	(0.010)	(0.010)	(0.021)	(0.014)	(0.014)	(0.014)	
S		0.854***	0.854***	0.859***		0.767***	0.772***	0.778***	
		(0.016)	(0.016)	(0.016)		(0.026)	(0.026)	(0.027)	
γ			0.023***	0.026***			0.040***	0.036***	
			(0.005)	(0.005)			(0.010)	(0.009)	
Observations	25,106	25,106	25,106	25,106	12,116	12,116	12,116	12,116	