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It is mainly about where you work!
Labor demand in the Colombian manufacturing sector

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Abstract

Using the Colombian Annual Manufacturing Survey (EAM) between 2000 and 2013, this paper investigates the existence of heterogeneity in the labor demand within the industrial sector. Long run own-price, output and TFP elasticities vary across a variety of dimensions such as regions, sectors and plant sizes depending on workers' skills and contract modalities (open-ended or temporary). Hence, it matters where one works. Such disparities should be taken into account in the design of policies that promote labor market performance, as outcomes, beyond intentions, are unlikely to be homogenous.

Key words: labor demand, skilled workers, unskilled workers, regional disparities, sector disparities.
JEL classification: *J*23, *R*32.

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1. Introduction

Labor demand in the manufacturing sector of Colombia has been studied at some length in recent years.[1] At least two reasons might explain this interest. First, the availability of information at plant level has promoted research efforts on the manufacturing sector. Second, the sector is plenty of valuable information given its high exposure to shocks of different nature: productivity, demand, foreign competition, incentives for physical capital accumulation, interest rate movements, periodical annual minimum wage updates, and exchange rate fluctuations, among many others. These shocks generate different dynamic responses not only in factor utilization and demands and, ultimately, in output that can be detected at the plant level.

However, previous studies fail to provide a complete picture of the employment behavior in the sector for policy makers, representatives of the industry, workers (trade unions), and job-seekers. In first place, due to sample differences, methodological changes to the Colombian Annual Manufacturing Survey (*EAM* is the Spanish acronym), and diverse theoretical and empirical approaches to estimations, no clear agreement emerges on the size of own-price and output elasticities of the labor demand.[2] In second place, regardless of the remarkable regional differences that characterize the Colombian labor market (Cárdenas, Hernández and Torres, 2014), such discrepancies have not been explained.[3] Thus, while important efforts have been made to estimate the labor demand in the manufacturing sector at national level, few present a regional focus.

Understanding such heterogeneity and its features is crucial as in these contexts labor market policies might produce diverse outcomes, even unintended ones, if it is not correctly factored in. Moreover, a clear grasp of these elements is likely to affect employment location and skill development strategies. Exploring these disparities requires acquiring insights on dimensions such as local productive structures, firm size and location. Given its employment potential, labor demand at the industry level is a natural variable to have into account.[4]

This paper sheds some light on these aspects. Using the information of the Annual Manufacturing Survey (EAM from its Spanish acronym) between 2000 and 2013, it addresses the heterogeneity of labor demand across regions, industrial subsectors and plant sizes.

Going beyond the estimation of aggregate labor demand elasticities to own-price, output and total factor productivity (TFP), as in existing literature, the paper innovates by discriminating across skills and contract modalities. By doing so, a clearer picture emerges as to the implications of

[1] See for example, Roberts and Skoufias (1997), Fajnzylber and Maloney (2001), Arango and Rojas (2003), Bernal and Cárdenas (2003); Eslava, Haltiwanger, Kugler, and Kugler (2010), and more recently Medina, Posso, Tamayo, and Monsalve (2013), among others. On the discussion about heterogeneity of results see for example Litcher, Peichl, and Siegloch (2014).

[2] Cross elasticities estimates are less abundant on these studies because of information lack about rental price of capital at plant level.

[3] In fact, Arango (2103) shows that the Colombian labor market exhibits important regional differences in labor market outcomes. For example, according to January 2016 data from the Colombia Statistical office (DANE), participation, occupation and unemployment rates show geographic differences that could exceed 10 percentage points, across cities. National unemployment rate (11.9%) is unevenly spread, from 7.6% (Bucaramanga) to 16% (Quibdó). Participation rates range from 59% (Quibdó) to 71.4% (Bogotá) and occupation rates from 49% (Quibdó) to 64% (Bogotá).

[4] Some of the papers in Arango, Castellani and Lora (2016, forthcoming) study among others geographic disparities of female unemployment rate.

shocks on skilled and unskilled, as well as permanent and temporary, labor demand. Results confirm that disparities do exist and labor markets are heterogeneous.

Complementing existing studies, the original contribution of this paper is to illustrate the nature of the regional, sector and size differences in the Colombian labor market and draw attention to the implication of this heterogeneity for labor policy design and outcomes.

The paper develops in five sections beyond this introduction. The second section presents a short literature review. The third section offers some stylized facts of the manufacturing sector. The fourth describes the theoretical approach and the fifth presents the empirical model and discusses the results. The sixth section concludes.

2. Literature review

Existing research on the determinants of labor demand in Colombia does not reach unanimous conclusions. Roberts y Skoufias (1997), using EAM data between 1981 and 1987, find that unskilled workers have a higher long run wage elasticity (-0.65) than skilled ones (-0.42). That is, the former are likely to be more effected by increasing labor costs. Output elasticities are higher for skilled labor (0.89) than for unskilled (0.76), suggesting that demand for output and skilled labor demand move almost proportionally. Regional dummies were included among the control variables.

Using data from the EAM and household surveys between 1980 and 1996, Vivas, Farné and Urbano (1998) find long run real wage and output elasticities of -0.71 and 1.10, respectively. Exploring the effects of trade liberalization on manufacturing labor demand between 1997 and 1999, Arango and Rojas (2004) obtain elasticities of -0.78 and 0.76 for real wage and output respectively. For a more recent subsample, the estimates turn to -0.92 and 0.67.

Bernal and Cárdenas (2003), based on the information of 2570 EAM establishments between 1978 and 1991, estimate the long-run real wage elasticity at -2.27 and the output elasticity at 0.24. With a panel of 91 manufacturing sectors, Bernal and Cárdenas (2003) find a short-run real wage elasticity of –0.6 and a long run one of –1.43. Eslava, Haltiwanger, Kugler, and Kugler (2010), focusing on joint factor demand and the incidence of adjustment costs find that the latter have been significant and substitutability rather than complementarity among factors emerge during the adjustment process.

Medina, Posso, Tamayo and Monsalve (2013) appraise the unconditional labor demand for the period 1993-2009, concluding that industrial employment is highly persistent. Production shocks generate the largest response of skilled and unskilled employment than shocks on capital and wages. Less skilled workers face higher adjustment costs.

Another strand of literature on labor market disparities relates to this paper. According to Dumais, Ellison and Glaeser (2002) geographic concentration in the U.S manufacturing industries has been declining over time. Dao, Furceri and Loungani (2014) observe lower migration rate among US states during the past 40 years due to higher labor market flexibility. In Europe, the participation rate response to labor demand shocks has been affected by migration. Beaudry, Green and Sand (2014) explore differences in labor demand introducing a special set of instruments and the local population size as a determinant of employment demand (see also Bartik, 2014).

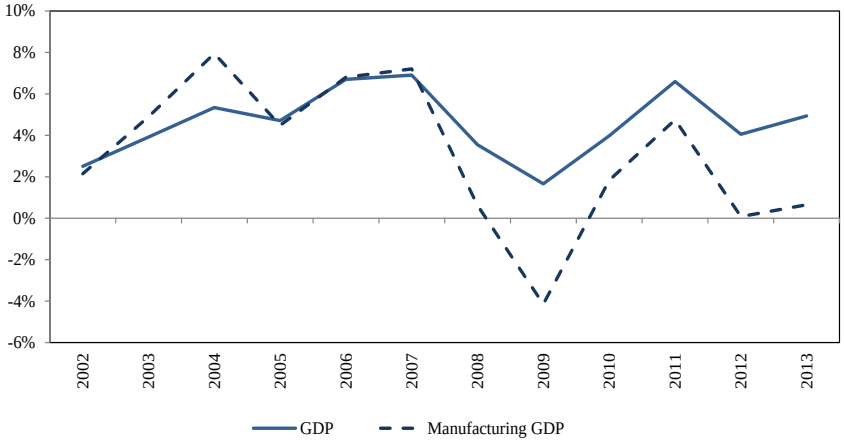
Resting on this literature and the findings of Arango (2013), this paper explores the industrial labor demand taking into account the potential regional, subsector and size disparities in Colombia. Our work is in the line of Adam and Moutos (2014) for the case of European countries.

3. Some behavioral facts of manufacturing sector

Colombian economic structure has considerably changed over the past four decades. In 1960s the manufacturing sector represented over 17% of GDP while in 2013 its share was 11.5%. The natural decline of agriculture and manufacturing sectors in GDP participation matched the rise of construction, trade and services. Between 2000 and 2013, the industrial sector maintained a 3.1% annual growth rate, severely interrupted by the 2008 crisis (Figure 1). In the aftermath, growth rate resumed at 1.8% per year, well below the rest of the economy (4.4%). The lackluster performance since then has been attributed to the real exchange rate appreciation and the consequent loss of competitiveness; trade-related demand disruptions, increasing labor costs, and poor infrastructure supply.[5] Still, manufacture remains as one of the most labor intensive sectors of the economy, being the fourth contributor to employment with 12.1%, according to the *Great Integrated Household Survey* (*GEIH* for its the Spanish acronym), after trade (27.4%), services (19.4%), and agriculture (17%). In 2013, the industrial sector accounted for 2,539,000 jobs at national level.

Hereafter, the paper uses the *Colombian Manufacturing Survey* (*EAM*) data, which includes 9,158 establishments (681,452 jobs) located in the 9 major cities (Barranquilla, Bogotá, Bucaramanga, Cali, Cartagena, Cúcuta, Manizales, Medellín, and Pereira) and "others".[6] The stylized facts from EAM endorse the heterogeneity identified by Arango (2013).

Figure 1. GDP and manufacturing GDP annual growth rates



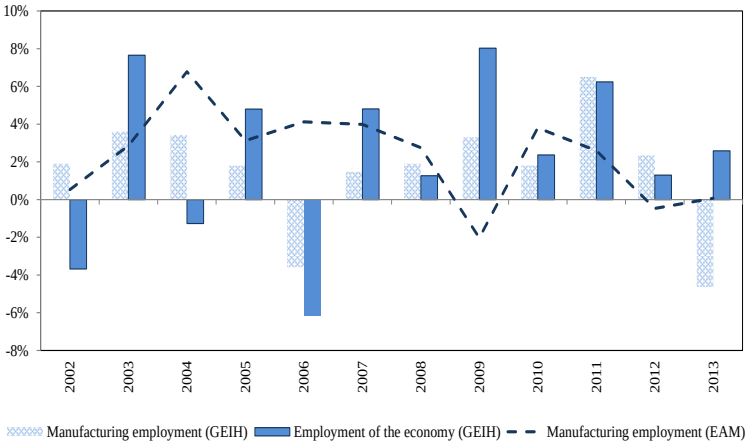
Source: DANE-EAM; authors' calculations.

[5] See Griffin (2015) for a discussion.
[6] 12,683 jobs are excluded as they are generated in small plants (less than 10 employees).

For the sake of comparison, Figure 2 shows the evolution of annual growth rate of employment taken from both sources, *GEIH* and *EAM*. The differences among the two sources are sizable. Indeed, pursuant to the former, the employment decreased 3.6% by 2006 while it grew just 1.9% and 3.3% in 2008 and 2009, respectively. Based on the *EAM*, the employment slowdown took place in 2009 when it decreased by more than 2%. Regardless of the disparities of the sources (*GEIH* and *EAM*), between 2002 and 2008, the annual growth rate of manufacturing employment surpassed the growth of total employment in five occasions: 2002, 2004, 2006, 2008, and 2010. After that, the performance of the sources and the results of the employment sector with respect to the total employment have also been very different.

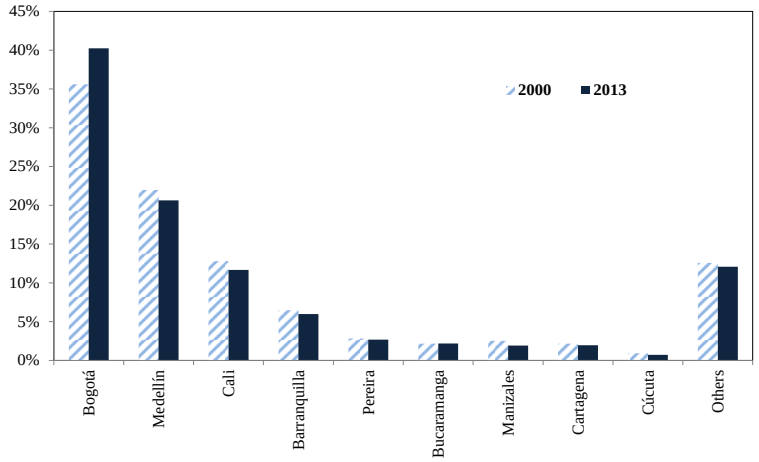
According to Figure 3, 80% of manufacturing employment concentrates in 4 cities (Bogotá, Medellín, Cali and Barranquilla), and Bogotá accounts for 40%. With the exceptions of Bogotá and Bucaramanga, all cities experienced a decline in their employment share since 2000.

Figure 2. Annual growth rates of total and manufacturing employment



Source: DANE-EAM; authors' calculations.

Figure 3. Contribution to employment of manufacturing sector by city (% of total)

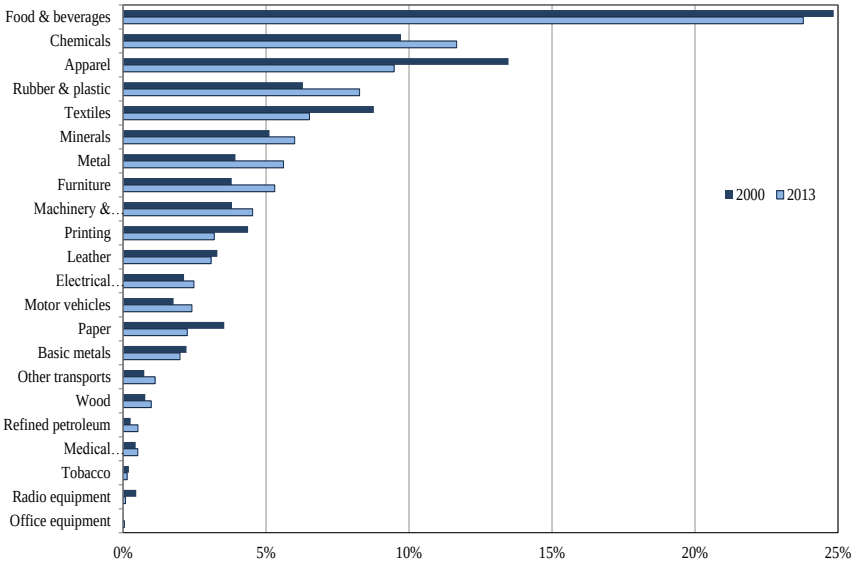


Source: Dane-EAM; authors' calculations.

Over the period, industrial employment expanded annually at 2.1%; however, geographically, patterns are uneven. Employment in Bogotá grew at 3.1% per year with an average annual growth rate of 4.6% before the crisis of 2008-2009, 2.1% during that episode[7] and 1.1% since 2010. In Cartagena employment grew at 2.1% but remained constant during 2008 and 2009. Manizales showed an average growth rate of 1.4% during the period 2000 and 2007 and 6.3% decline during the crisis. In Pereira volatility was significant along the sample period. Barranquilla provides an interesting case: with an unappealing evolution before 2009, employment increased at 3% annually since 2010. Cúcuta and Manizales displayed dismal growth rates of 0.4% and 0.2%, respectively.

Six sectors -food and beverages, chemicals, apparel, rubber and plastic, textiles, and minerals- account for 66% of total employment.[8] While remaining the most labor intensive, their participation to employment varies overtime in an unsteady fashion. Chemicals, rubber and plastic, mineral, and metals record sizable increments overtime and food and textile decline (Figure 4).

Figure 4. Labor intensity by sector and city 2000 – 2013

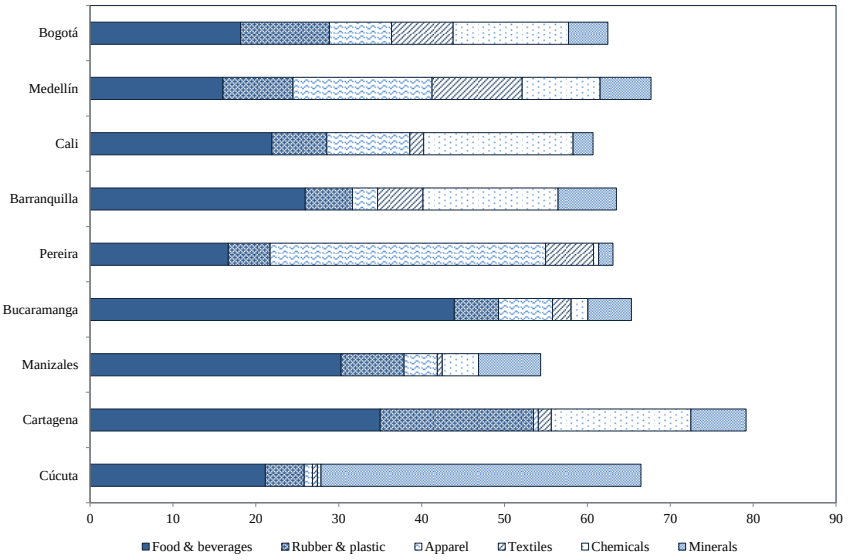


Source: Dane-EAM; authors' calculations.

Labor intensity varies across cities. Barranquilla generates only a few jobs in apparel while Cali does so in textiles. Food is the largest job generator representing 44% of total employment in Bucaramanga, 35% in Cartagena and 30% in Manizales (Figure 5). Apparel has been very important employer sector in Pereira, Medellín and Cali. Bogotá, Medellín, Cali and Barranquilla have plants devoted to the production of all six subsectors.

[7] In 2009, the annual growth rate was -0.9%.
[8] If we add metal and furniture, the total employment corresponds to 76.7% of the sample in 2013.

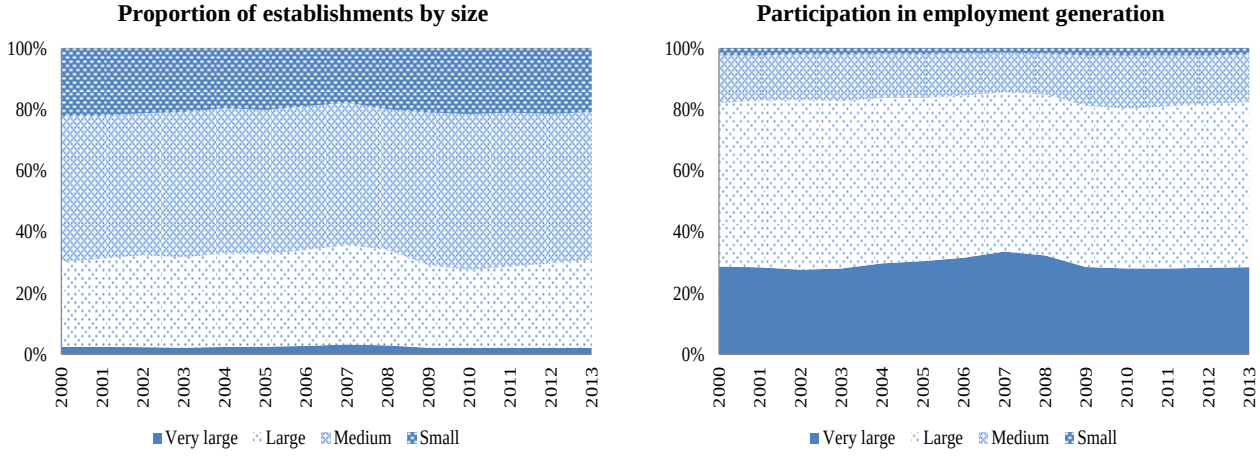
Figure 5. Labor intensity by subsector and city 2013



Source: Dane-EAM; authors' calculations.

Colombian business landscape is populated by small and medium size establishments and manufacturing is not an exception. On average, medium size manufacturing plants account for 48% of the total sample, generating 15% of the employment.[9] Large and very large ones represent 32% of establishments and 83% of the total employment; small plants, 21% of total, only contribute to 1.8% of employment (Figure 6). In line with 2013 data, Bogotá, Medellín, and Cali are the preferred locations, concentrating 73% of the establishments. Since 2000, a growing proportion of businesses opt for Bogotá and very large establishments pick Bogotá over Medellín and Cali. Interestingly, Barranquilla experiences a surge in the number of larger plants from 31% in 2000 to 39% in 2013 (Figure 7).

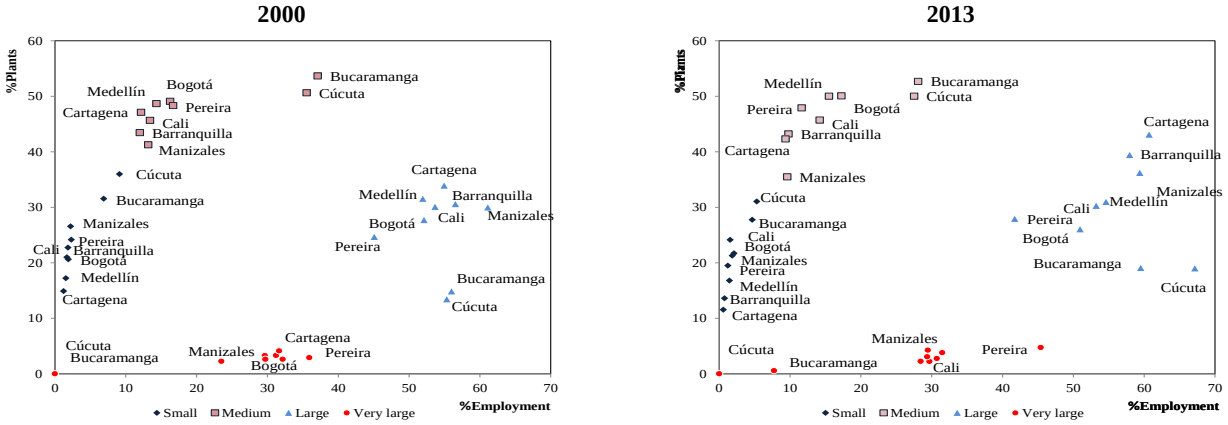
Figure 6. Establishments by size and employment shares



Source: Dane-EAM; authors' calculations.

[9] In this study, small sized establishments are those that employ 10 people or less, medium sized between 11 and 50, large between 51 and 500 and very large more than 500.

Figure 7. Establishments distribution by size and cities (% of total)



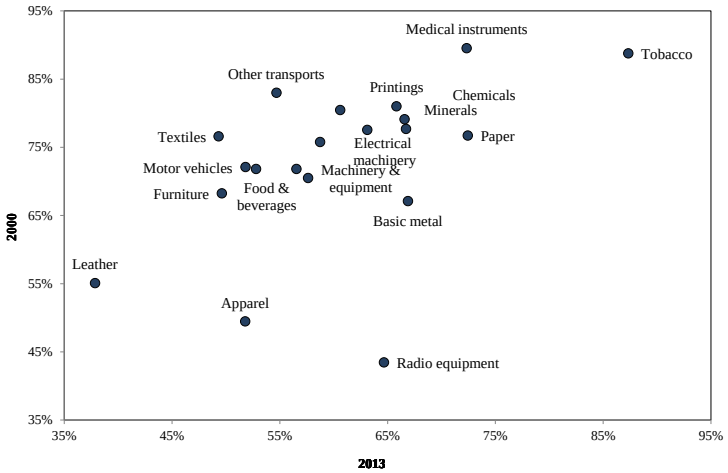
Source: Dane-EAM; authors' calculations.

No clear pattern emerges as to sector of specialization by firm. Food and beverages, textiles, rubber and chemicals are characterized by plants of all sizes, yet very large plants seem more likely to specialize in the production of textiles, food and beverages and electrical machinery.

Overtime contract modalities in the manufacturing sector show remarkable changes, with the share of open-ended contracts declining from 71% (2000) to 61% (2013), in favor of temporary ones. While this shift applies generally to all subsectors, intensities vary (Figure 8).

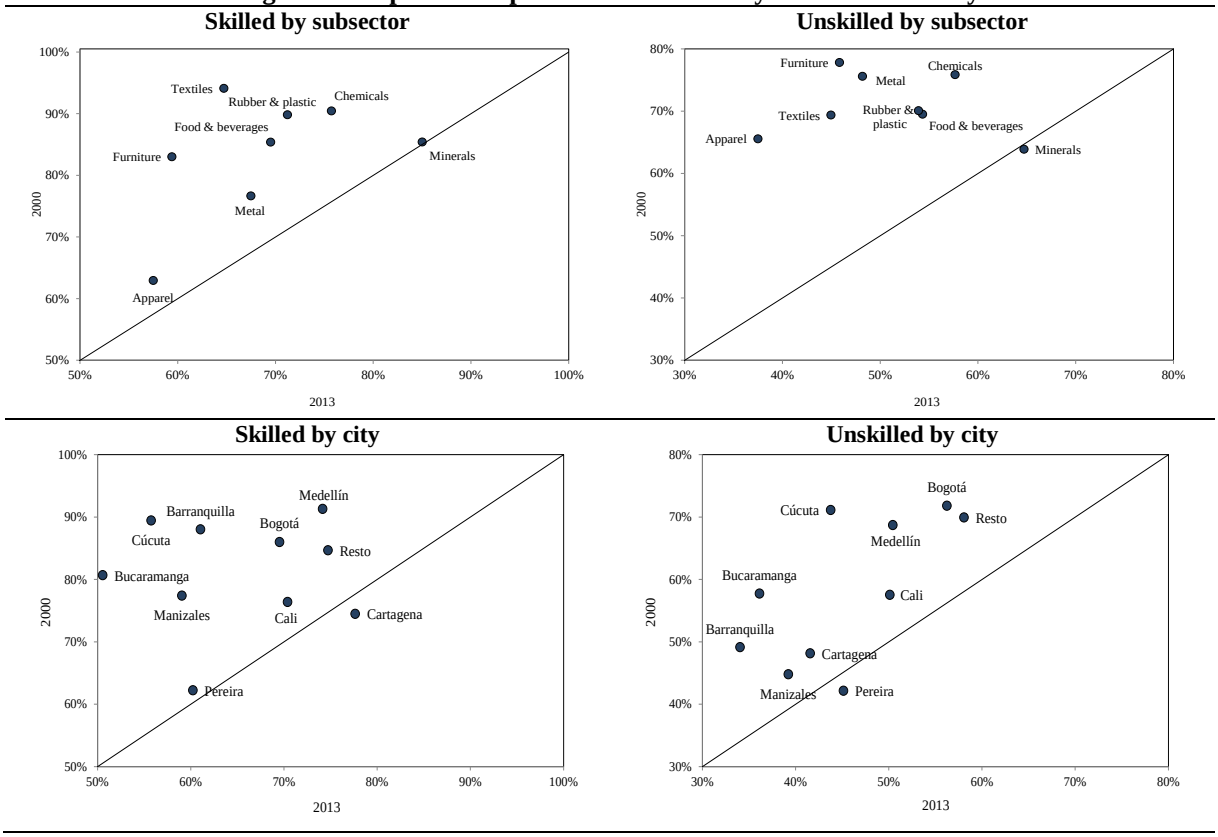
The proportion of open-ended contracts among skilled workers decreases considerably in subsectors such as textiles, rubber and plastic, food and beverages, chemicals, and furniture. Unskilled workers experience this contract substitution to a greater extent between 2000 and 2013. In apparel, the proportion of unskilled employees with open-ended contracts as a percentage of total unskilled employment almost halves from 66% to 37%. In textiles, this proportion changes from 69% to 45%. Cúcuta, Bucaramanga and Barranquilla witness the largest switch to temporary contracts (Figure 9).

Figure 8. Permanent (open-ended) contracts by subsector in 2000 and 2013. % of total



Source: Dane-EAM; authors' calculations.

Figure 9. Proportion of permanent workers by subsector and city



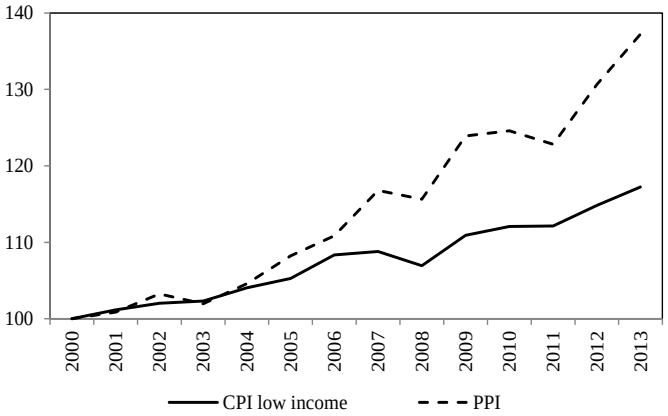
Source: Dane-EAM; authors' calculations.

Changes to less permanent forms of contracting might be related to high labor costs: minimum wage and non-wage labor cost. The latter, until 2011 accounted for nearly 60 percentage points of the wage[10] for workers earning less than ten minimum wages. At the same time, the real minimum wage has systematically increased above inflation and labor productivity, amplifying labor costs (Figure 10).

Along with more temporary modalities, the share of skilled labor force increases throughout the industry. The largest increases in the skill-content of production take place in chemicals, furniture, and apparel. Chemicals, rubber and plastic, and food and beverages show the highest ratios of skilled to total workers while apparel, furniture and textiles the smallest ones (Figure 11). Minerals is the only subsector where no changes occur. By cities, Cartagena, Cali and Barranquilla have the highest proportion of skilled workers whereas Cúcuta, Pereira and Bucaramanga use the smallest proportion. Barranquilla, Manizales, and Cali double the proportion of skilled labor force over time.

[10] The 2012 tax reform, among other things, modified the non-wage labor costs reducing them by 13.5 percentage points.

Figure 10. Real minimum wage (2000=100)



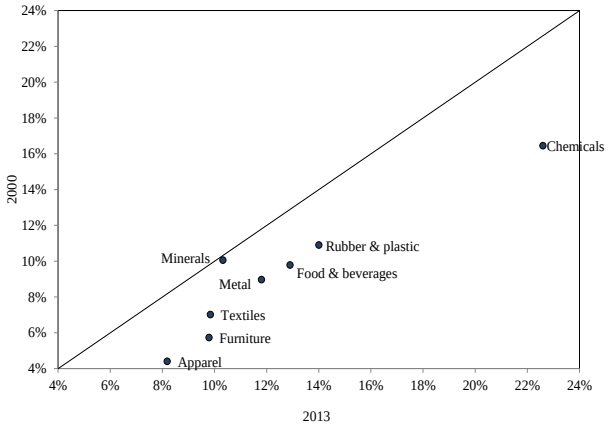
Note: CPI= consumer price index; PPI= producer price index. Source: Dane-EAM and Banco de la República; authors' calculations.

Employment shows a gender bias, captured by the male-female labor ratio. The minerals subsector displays the largest bias towards male workers with a ratio of 6.3 men for each woman, followed by metal with a ratio of 4 (Figure 12). Apparel is biased towards female labor force with the proportion of 3 to 1. Basic metals, motor vehicles, and machinery and equipment employ more men than women.[11] Skilled employment features higher gender bias than unskilled. Permanent positions are more often male dominated than temporary ones.

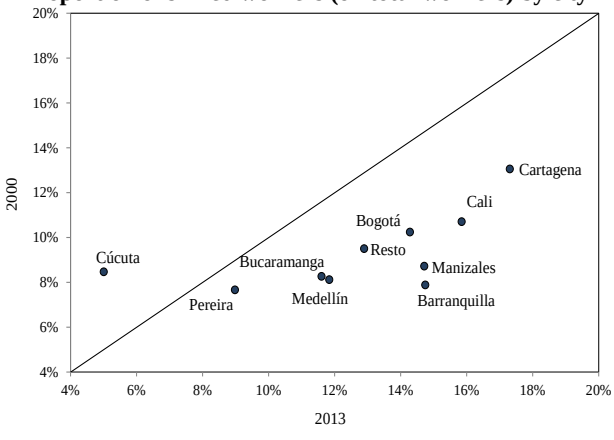
Among the most labor intensive subsectors, food and beverages, chemicals and minerals exhibit the highest labor productivity while apparel generates the lowest output per-worker (Figure 13). At the same time, this subsector has a low real wage and capital per worker. Apparently, the higher the capital per worker, the higher the real wage (Figure 14).

Figure 11. Skill distribution by sector and city

Proportion of skilled workers (on total workers) by sector



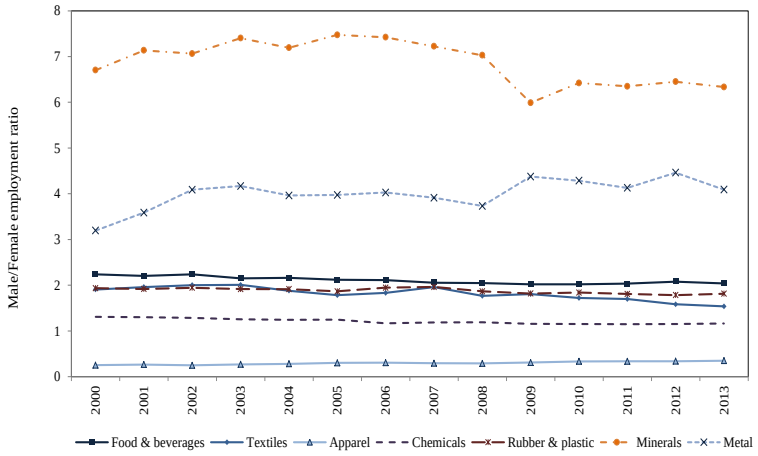
Proportion of skilled workers (on total workers) by city



Source: Dane-EAM; authors' calculations.

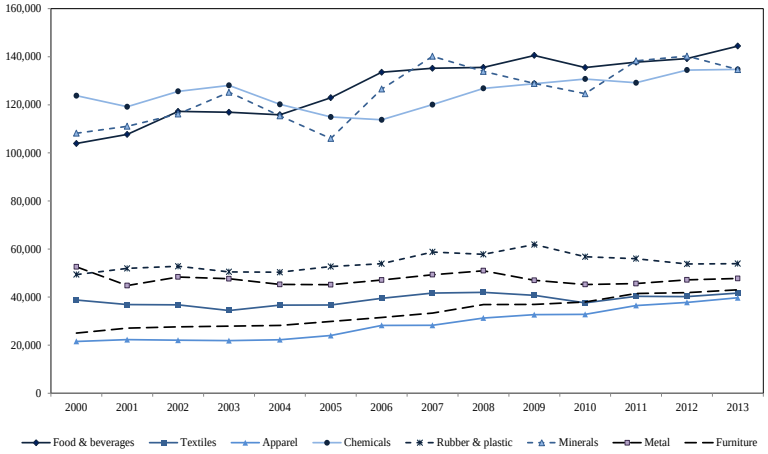
[11] The ratios of these three subsectors are not shown in Figure 10 since they are not among those more labor intensive in the industrial sector.

Figure 12. Gender intensity ratio by (selected) sector: male to female employment ratio



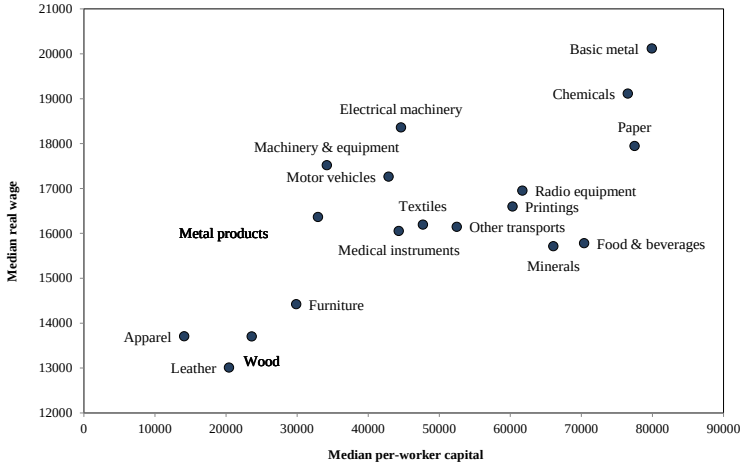
Source: Dane-EAM; authors' calculations.

Figure 13. Real per-capita added value by subsector (2000=100)



Source: Dane-EAM; authors' calculations.

Figure 14. Median real wage and median capital per-capita (2000=100)



Source: DANE-EAM; authors' calculations.

4. Theoretical approach and empirical model

Labor demand theory sets out the variables considered by firms to hire or dismiss employees, such as product demand, labor cost and other costs (capital, energy power, etc.), technology, taxes, subsidies, among others. Within a static framework of the competitive model, the conditional labor demand is obtained by minimizing the total costs subject to a given level of production and depends on product demand, technology, and relative factor prices. Thus, if there is a change in the latters, everything else constant, labor and capital will be combined in different proportions since they are substitutable.[12] Labor and capital demands depend on relative prices and production levels; that is: $l(r/w\,, y, A; \alpha)$ and $k(w/r\,, y, A; \alpha)$, where w, r, y, A and α are real wages, real rental price of capital, output, technology, and parameters of the production function. The unconditional factor demands, derived from the utility maximization process, take the form: $l(w, r, A; \alpha)$ and $k(w, r, A; \alpha)$.

However, given the presence of adjustment costs, generated by firms' desires to reach a certain equilibrium level of labor in the production process, and uncertainty within a dynamic context, factor demand turns out to be different from the above specifications (see Hamermesh, 1993; Cahuc and Zylberberg, 2004; Wickens, 2011). The framework used to address the estimation of the labor demand includes quadratic and symmetric adjustment costs. Typically, the firm maximizes:

$$\Pi_t = E_t\left\{\sum_{j=0}^{\infty}(1+r)^{-j}\left[F\left(l_{t+j}, A_{t+j}\right) - w_{t+j}l_{t+j} - 0.5a\left(l_{t+j} - l_{t+j-1}\right)^2\right]\right\}$$

where E_t represents the expectations operator, r_t the interest rate, l_t the number of employees, and A_t shocks of different nature that affect the firm's product supply. From the first order conditions:

$$\Delta l_{t+j} = E_t\left\{\frac{F_l\left(l_{t+j}, A_{t+j}\right) - w_{t+j}}{a} + \frac{\Delta l_{t+j+1}}{(1+r)^{j+1}}\right\} \qquad j = 0, 1, ..$$

By replacing forward, this expression can be rewritten as:

$$\Delta l_{t+j} = E_t\left\{\sum_{j=0}^{\infty}\frac{F_l\left(l_{t+j}, A_{t+j}\right) - w_{t+j}}{a(1+r)^j}\right\}$$

Thus, if the present value of the marginal product of labor is greater than the present value of wages, the number of employees will increase. Assuming rational expectations the model (see Sargent, 1978; Nickel, 1984; Hamermersh, 1993; and, Cahuc and Zylberberg, 2004) can be written as:

$$l_t = \lambda l_{t-1} + \sum_{m=1}^{K}\sum_{j=0}^{J_m}\mu_{mj}X_{m,t-j}$$

By using the notation of Hamermesh (1993, chapter 7), the empirical model can be written as:

$$l_{i,t} = \lambda l_{i,t-1} + \sum_{m=1}^{K}\sum_{j=0}^{J_m}\mu_{m,j}X_{i,m,t-j} + \omega_{i,t}$$

where index i accounts for plant i, $X_{i,m,t-j}$ is the vector of observable variables including the average real wage paid by the firm, added value of the firm, TFP indicator, etc.; $\mu_{m,j}$ is the vector of coefficients to be estimated, and $\omega_{i,t}$ is the residual term. With the aim of having information about

[12] If capital, k, and labor, l, are both strictly required for the production process in given proportions, then they are said to be complementary.

the adjustment costs, the empirical model holds just one autoregressive element (Hamermersh, 1993) which can be separated from the expectations of remaining variables based on past realizations.

Potentially, the residual term is the sum of different elements: $\omega_{i,t} = \eta_i + \upsilon_{i,t} + \varepsilon_{i,t}$. The first component, η_i, accounts for unobserved heterogeneity directly linked to plant characteristics other than the price of inputs and usual determinants of labor demand (see Roberts and Skoufias, 1997). The list of plausible candidates includes especial properties of output, the relative advantages to combine inputs in the production process, etc. The second element, $\upsilon_{i,t}$, can be related with shocks to the demand product or to the supply of labor specific to the production of the plant, etc. These first two elements of the unobserved heterogeneity could eventually be correlated to the output of the plant as well as the wage $\left[E(\eta_i|X_{i,m,t}) \neq 0\right]$ and $\left[E(\upsilon_{i,t}|X_{i,m,t}) \neq 0\right]$; as a result the respective coefficients could be biased upwards. The third element, $\varepsilon_{i,t}$, is a well behaved random component.

Another issue to be addressed is the potential endogeneity (reverse causality) of real wage and the establishment output. To face this problem, instrumental variables as well as some moment conditions are used. Arellano and Bover (1995) and Blundell and Bond (1998) indicate that lagged levels are often rather poor instruments for first differenced variables, especially if the variables are close to a random walk. Thus, the paper adopts the Blundell and Bond (1998) GMM estimator where both lagged levels and lagged first differences can be combined as instruments to improve efficiency of the estimator. As the two-step system GMM estimator presents downwards bias, the Windmeijer (2005) correction is also used.

The paper combines skilled and unskilled with permanent and temporary employment, and explores the regional, sector, and size dimensions of heterogeneity. The resulting estimations provide elasticities for (i) the 9 major cities (Barranquilla, Bogotá, Bucaramanga, Cali, Cartagena, Cúcuta, Manizales, Medellín, and Pereira) and "others"; (ii) the most labor intensive sectors (food and beverages, chemicals, apparel, rubber and plastic, textiles, mineral, metals, and furniture) and different plant sizes (medium, large, and very large plants). For each of these dimensions the elasticities are estimated for skilled and unskilled workers with permanent and temporary contracts. Skilled workers are defined as those with tertiary education -technical, technological or professional- while unskilled workers are those without any education beyond high school.

To take advantage of the panel structure of the Annual Manufacturing Survey the paper uses information at establishment level between 2000 and 2013. The smallest number of plants of our unbalanced panel is 6801 in 2003 while the highest is 9867 in 2010. The number of plants was 9158 in 2013, the last year of the sample.

The empirical specification sets demand for labor in terms of its own lag, contemporary and lagged values of real wages, output, total factor productivity, the real minimum wage, energy prices, and the real interest rate. The log of number of employees is the dependent variable. The variables on the right-hand side are: the lag of the dependent variable, the log of the current and lagged value of: average real wage, added value of the firm, real minimum wage, real interest rate, TFP, and energy price. The specification also includes the current value of the depreciation rate. Average real wage, minimum wage and added value starting at lag two are used as instruments. Most of the

results below correspond to long run elasticities which are computed as: $\epsilon_j = (\mu_{m,0} + \mu_{m,1})/(1-\lambda)$, m is real wage, output, and TFP, respectively.

As the EAM does not have information about individual real wages, these were computed by dividing, respectively, the payroll in real terms among the number of skilled and unskilled workers. Output corresponds to the total added value in each plant, as well as the energy prices and the depreciation rate. The total factor productivity was computed by using the Levinshon and Petrin (2003) algorithm. Finally, the real interest rate corresponds to ordinary and preferential interest rates,[13] since the real rental price of each plant is not available.

5. Results

Table 1 shows own real price, output, and TFP long-run elasticities under conditional and unconditional specifications of labor demand for skilled and unskilled workers. Wage elasticities of skilled (-0.591) and unskilled workers (-0.415) are both significant. Contrary to existing literature (see Litcher *et al*., 2014 and, for the case of Colombia, Roberts and Skoufias, 1997), skilled employment shows a larger sensitivity to its own price. When estimations take into account contract modalities, the long-run real wage elasticity of open-ended contracts workers is larger than temporary, irrespective of their skills. Increased flexibility in the labor market institutions and growth in labor intermediation over the sample period might explain this larger response. Unskilled workers are generally more sensitive than skilled ones, in line with previous research. Moreover, under the conditional specification, the temporary unskilled workers show an elasticity of -0.438 and the skilled of -0.256. Similarly, the elasticity to the real wage of demand for unskilled workers with open-ended contracts is -1.109 and -0.682 for the skilled permanent workers. In general, according to Hansen test the set of instruments is accurate and the Ar2 test shows that the errors do not exhibit autocorrelation of order two.

The output long-run elasticity is higher than the real wage elasticity as in earlier studies. Permanent workers (0.949-skilled and 1.198-unskilled) show larger responsiveness than temporary ones (0.710-skilled and 0.760-unskilled). However, skilled (1.122) are more sensitive than unskilled workers (1.051).

The theory predicts a negative sign of the response to TFP in the case of the conditional labor demand and a positive one for the unconditional demand. These predictions match the estimates for both types of workers, with a larger response for permanent employees. The respective elasticities, corresponding to the conditional demand specification, for skilled workers are -0.773 and -0.621 while for unskilled workers the elasticities are -1.043 and -0.73. Demand for skilled workers, regardless of the type of contract, displays lower TFP elasticity and more resilience to changes in technology.

[13] The difference between these two interest rates is the size of the plant. Preferential is the interest rate of loans granted to large and very large establishments (about 32% of the plants) while ordinary is the interest rate of credits requested by medium size establishments.

Table 1. Long-run labor demand elasticities (2000-2013).

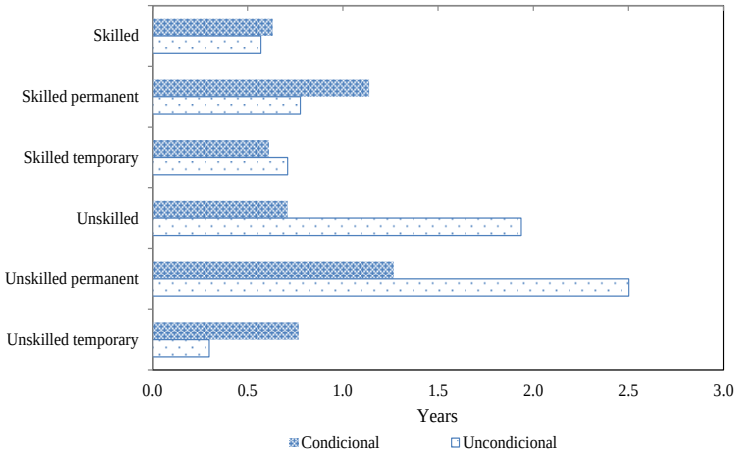
Specification	Conditional	Unconditional
Skilled workers		
Own-price	-0,591***	-0,316***
Output	1,122***	
TFP	-1,016***	0,326*
No. observations (plants)	14,579	14,579
Sargan test (p-value)	7.68e-10	0.000381
Hansen test (p-value)	0.102	0.808
Ar2 (p-value)	0.540	0.969
Skilled permanent workers		
Own-price	-0,682***	-0,517***
Output	0,949***	
TFP	-0,773***	0,753***
No. observations (plants)	13,062	13,062
Sargan test (p-value)	0.000466	1.73e-05
Hansen test (p-value)	0.213	0.514
Ar2 (p-value)	0.700	0.398
Skilled temporary workers		
Own-price	-0,256***	-0,251***
Output	0,710***	
TFP	-0,621***	0,590*
No. observations (plants)	4,477	4,477
Sargan test (p-value)	3.11e-07	0.000946
Hansen test (p-value)	0.467	0.761
Ar2 (p-value)	0.443	0.464
Unskilled workers		
Own-price	-0,415***	0,074
Output	1,051***	
TFP	-0,951***	0,261
No. observations (plants)	20,470	20,470
Sargan test (p-value)	0.0353	0.730
Hansen test (p-value)	1.21e-05	0.000113
Ar2 (p-value)	0.618	0.346
Unskilled permanent workers		
Own-price	-1,109***	-0,865***
Output	1,198***	
TFP	-1,043***	0,429
No. observations (plants)	17,502	17,502
Sargan test (p-value)	6.32e-08	1.06e-07
Hansen test (p-value)	0.637	0.589
Ar2 (p-value)	0.339	0.513
Unskilled temporary workers		
Own-price	-0,438***	-0,107
Output	0,760***	
TFP	-0,730***	0,223
No. observations (plants)	12,579	12,579
Sargan test (p-value)	0	0
Hansen test (p-value)	0.000153	0.00401
Ar2 (p-value)	0.702	0.00624

Source: Dane-EAM; authors' calculations.

Under the unconditional specification, the own-price elasticity is significant for skilled workers and for unskilled permanent. At the same time, TFP elasticity is significant only for skilled workers and has the right sign in the three cases. This labor demand specification does not seem appropriate for unskilled employees.

The empirical specification allows estimating the speed of adjustment of labor demand (halfway or half-life of the adjustment) to shocks in output or factor prices. The median length is computed by solving for t^* the expression $\lambda^{t^*} = 0.5$. Under the conditional specification, the halfway ranks between 0.61 and 1.27 years (Figure 15), corresponding to skilled temporary workers and unskilled permanent ones, pointing at a shorter adjustment period for higher level of skills and more flexible contracts. These results are consistent with existing estimates using annual data which show halfways of 5.5 quarters (Hamermesh, 1993, page, 253). In the following three sections, regional, sector, and size heterogeneity are analyzed based on the conditional specification, which corresponds to the constant product labor demand.

Figure 15. Halfways of labor demand adjustments (2000-2013).



5.1 Regional heterogeneity

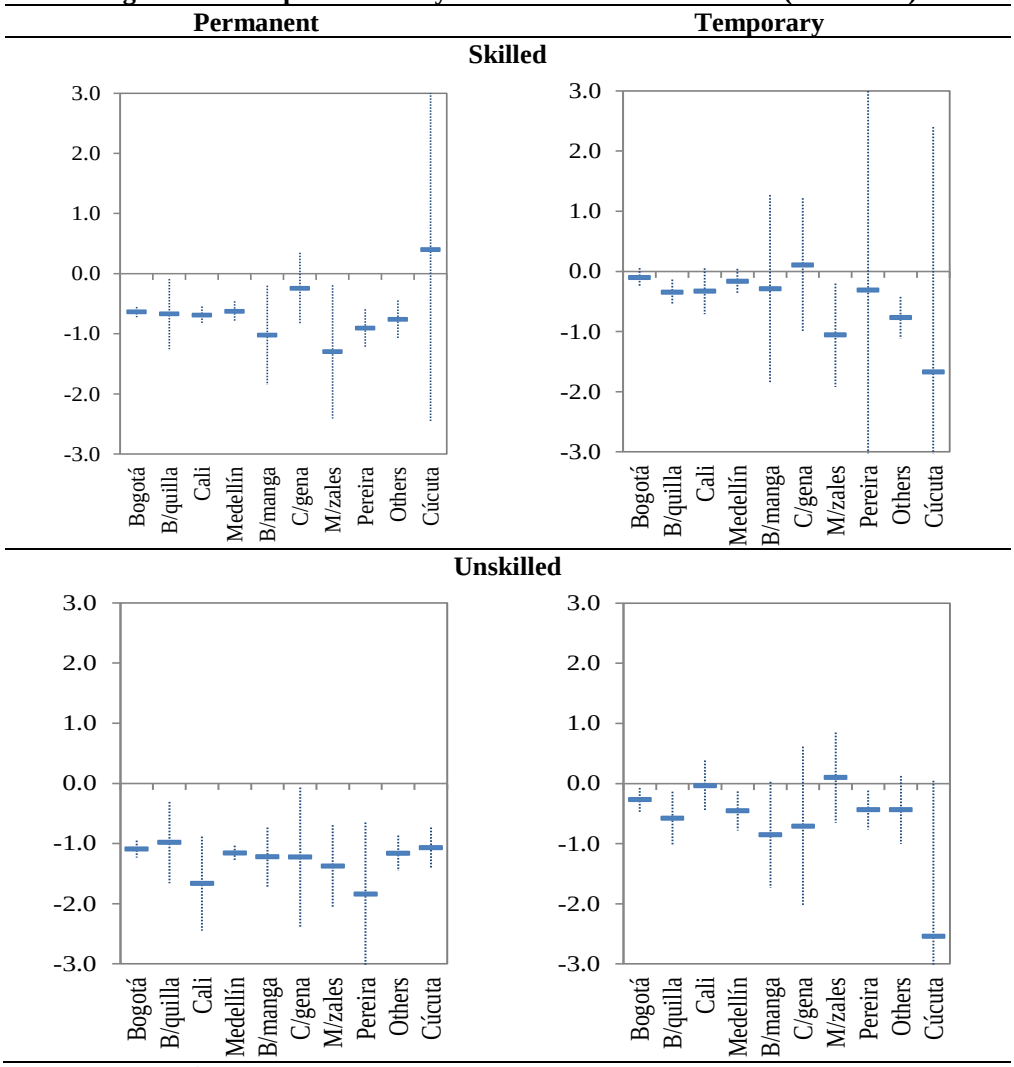
As mentioned before, labor market outcomes present significant disparities across metropolitan areas in Colombia. Elasticities are estimated across 9 major cities to verify labor market regional heterogeneity (Figure 16). Results indicate that besides Cartagena and Cúcuta, whose elasticities are not statistically significant, real wage long-run elasticities of permanent skilled workers are negative and significant and range between -1.3 (Manizales) and -0.632 (Medellín).

In the case of skilled workers with temporary contracts, the highest own price elasticity corresponds to Manizales (-1.061). For permanent unskilled workers, the greatest value is found in Pereira (-1.843) and the smallest in Barranquilla (-0.983). In the case of unskilled temporary workers, the elasticity varies between -0.27 (Bogotá) and -0.58 (Barranquilla) and only these two cities together with Medellín and Pereira hold significant long-run elasticities. Consistently with Figure 16, the geographic breakdown confirms that demand for temporary workers, both skilled and unskilled, is less responsive to its own price than permanent ones.

The length of adjustment to shocks is greater for unskilled and permanent workers. Once there is a change in the real wage, permanent workers are more likely to be displaced and possibly replaced by temporary ones. Bogotá shows consistently faster adjustment speed than the rest of the cities across skills and contract modalities (Figure 17).

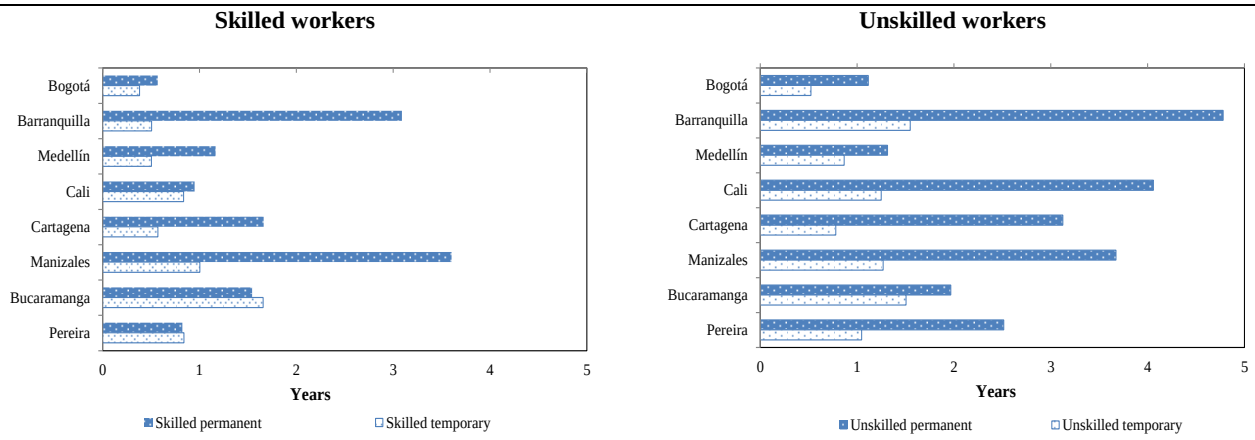
Output elasticities, with the exception of Cúcuta, all are positive (Figure 18). However, significant long-run reactions to output for permanent skilled labor are obtained for plants in Bogotá, Cali, Cartagena, Medellín, and Pereira. In the case of temporary skill, only Bogotá and Medellín are significant. Demand for permanent unskilled employees is significant in Cali (1.702), "others" (1.241), Bogotá (0.987), Medellín (0.833), Barranquilla (0.814), and Bucaramanga (0.723). The lowest estimate for temporary unskilled workers is found in Medellín (0.619) and the highest in Manizales (4.047). Elasticities to TFP are negative in most cases as predicted by the theory under the conditional specification (Figure 19).

Figure 16. Own price elasticity of conditional labor demand (2000-2013)



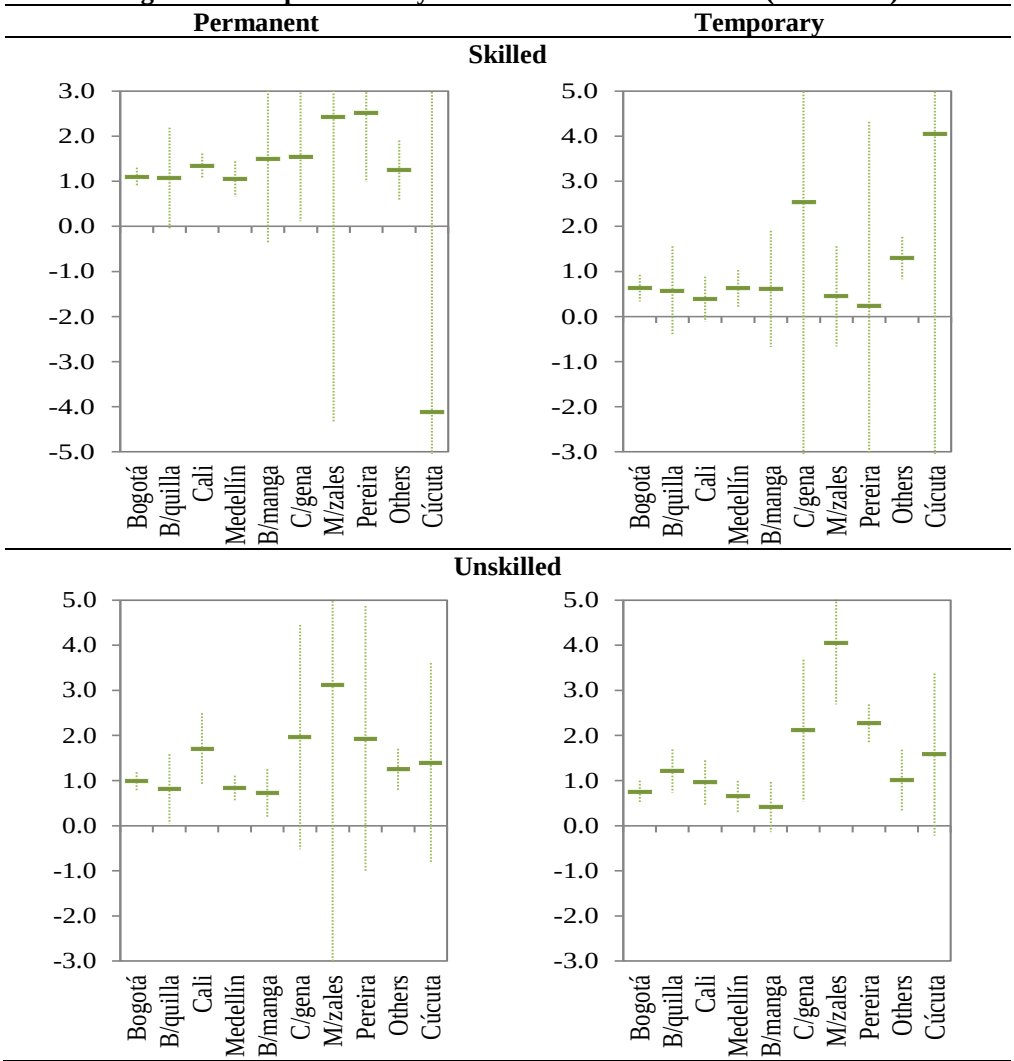
Note: 95% confidence intervals. Source: Dane-EAM; authors' calculations.

Figure 17. Halfway of labor demands adjustments of a real wage movement by city
Conditional demand for labor



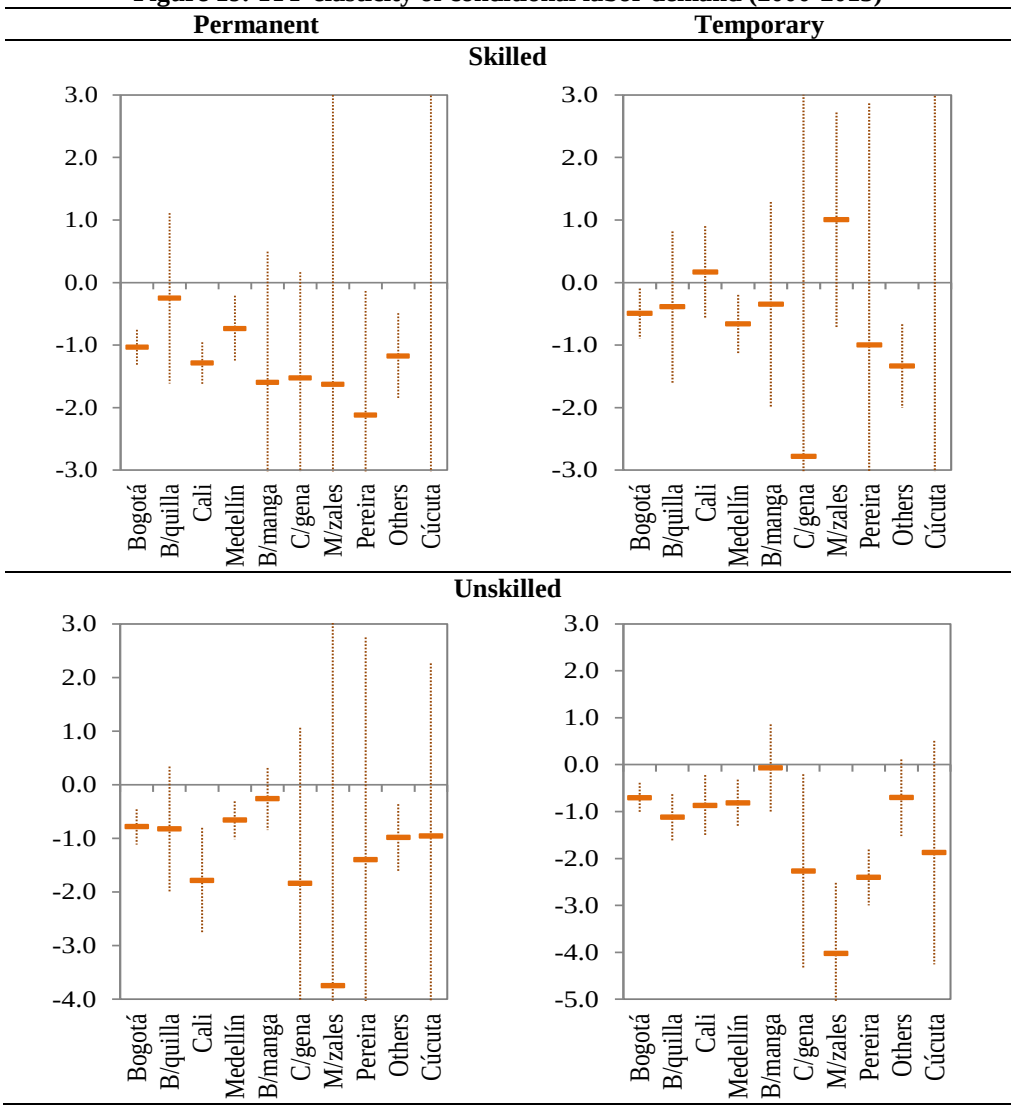
Source: Dane-EAM; authors' calculations.

Figure 18. Output elasticity of conditional labor demand (2000-2013)



Note: 95% confidence intervals. Source: Dane-EAM; authors' calculations.

Figure 19. TFP elasticity of conditional labor demand (2000-2013)



Note: 95% confidence intervals. Source: Dane-EAM; authors' calculations.

The heterogeneity of the determinants of conditional labor demand seems a prevalent characteristic of the manufacturing sector in Colombia. The hypothesis that the difference between each pair of coefficients is equal to zero can be rejected in most cases (Tables 2 and 3). Based on the tests of mean-differences carried out under the assumption that distributions are independent, the null hypothesis that the elasticities of each type of demand for labor are equal for most of combinations of cities can be rejected. In Table 2, in the case of permanent contracts, the lower part of the matrix (below the diagonal), the labels "O" indicates that the null hypothesis that the long-run wage elasticities of skilled workers are equal between each pair of cities cannot be rejected at 5% level of significance. Cali and Barranquilla are the only metropolitan areas where long-run wage elasticities are statistically equal. With respect to output elasticity of demand for skilled workers, the null hypothesis that the coefficients are the same between each pair of cities cannot be rejected at 5% level of significance in the following cases: Bogotá-Barranquilla, Medellín-Barranquilla, Bucaramanga-Cartagena, and Manizales-Pereira. For TFP elasticities, the pairs of cities in which

the coefficients are statistically similar are Bucaramanga-Cartagena, Bucaramanga- Manizales, Cali-Manizales and Cartagena-Manizales.

In the upper-right section of Table 2 (above the diagonal), where the equality of unskilled elasticities is tested, the labels "X" suggest that the null hypothesis cannot be rejected at 5% of significance. As a result, in the case of real wage elasticity, Bogotá and Cúcuta have the same coefficient as well as Medellín and "others" but most of the coefficients are not statistically equal to each other. For output, similar elasticities are found in the following pairs: Medellín-Barranquilla, Pereira-Cartagena, and Cúcuta-Pereira. TFP elasticities are similar in Cúcuta-Bogotá, Cúcuta-Barranquilla, and Cúcuta-"others".

Table 2. Similarity of elasticities tests on conditional labor demand for permanent workers

Unskilled → / Skilled ↓	Bogotá			Barranquilla			Bucaramanga			Cali			Cartagena			Manizales			Medellín			Pereira			Others			Cúcuta		
	w	*y*	*tfp*	*w*	*y*	*tfp*	*w*	*Y*	*tfp*	*w*	*y*	*tfp*	*w*	*y*	*tfp*	*w*	*Y*	*tfp*	*w*	*y*	*tfp*	*w*	*y*	*tfp*	*w*	*y*	*tfp*	*w*	*y*	*tfp*
Bogotá																												X		X
Barranquilla		O																		X										X
Bucaramanga													X																	
Cali				O																										
Cartagena								O	O														X							
Manizales									O			O			O															
Medellín					O																					X				
Pereira																	O												X	
Others																														X
Cúcuta																														

Source: Dane-EAM; authors' calculations.

The tests in Table 3 -temporary employees- suggest that the null hypothesis cannot be rejected for 8 out of 45 possible combinations of cities for real wage elasticity in the case of skilled workers; these pairs are: Bogotá-Pereira, Cali-Barranquilla, Bucaramanga-Barranquilla, Cali-Bucaramanga, Pereira-Barranquilla, Pereira-Bucaramanga, Pereira-Cali, and Pereira-Medellín. Similar output elasticities are found for Bogotá-Bucaramanga, Bogotá-Medellín, Barranquilla-Bucaramanga, Barranquilla-Medellín, Bucaramanga-Medellín, Cali-Manizales, Cali-Pereira, and Manizales-Pereira. TFP elasticity for temporary skilled workers is similar in Barranquilla-Bucaramanga, and Cartagena-Cúcuta.

Thus, the employment in the industrial sector shows a high geographic heterogeneity. Nevertheless, Bucaramanga and Barranquilla are similar in some dimensions of industrial temporary employment. Recall, that according to Figure 9 above, lower panels, an important reduction in these two cities of permanent workers took place between years 2000 and 2013.

Table 3. Similarity of elasticities tests on conditional labor demand for temporary workers

Unskilled → / Skilled ↓	Bogotá			Barranquilla			Bucaramanga			Cali			Cartagena			Manizales			Medellín			Pereira			Others			Cúcuta		
	w	*y*	*tfp*	*w*	*y*	*tfp*	*w*	*Y*	*tfp*	*w*	*y*	*tfp*	*w*	*y*	*tfp*	*w*	*y*	*Tfp*	*w*	*y*	*tfp*	*w*	*y*	*tfp*	*w*	*y*	*tfp*	*w*	*Y*	*tfp*
Bogotá																											X			
Barranquilla																														
Bucaramanga		O		O	O	O																								
Cali				O			O																							
Cartagena																														
Manizales											O																			
Medellín		O			O			O														X								
Pereira	O			O			O			O	O						O		O											
Others																														
Cúcuta															O															

Source: Dane-EAM; authors' calculations.

5.2 Sector heterogeneity

Disparities of labor demand also emerge across industrial subsectors. To simplify the analysis, estimates are restricted to the most labor intensive subsectors (Figure 4)[14] under the conditional specification. The demand for permanent skilled workers displays larger responses to real wages than temporary employees (Figure 20). At the same time, permanent unskilled workers are more sensitive than skilled ones. Food products, chemicals, and rubber and plastic show significant elasticities. The lowest value is found for temporary skilled workers in chemical plants (-0.284) and the highest for unskilled workers in textile plants (-2.157).

For skilled workers, the median adjustment length by subsector varies between 0.5 (temporary) and 2.26 years (permanent). The shortest halfway corresponds to rubber and plastic subsector and the longest to chemicals (Figure 21). For unskilled workers, the halfways range between 0.97 (mineral products) and 6.2 (textiles) years. A partial conclusion is that adjustment costs for unskilled workers are lower.

For skilled permanent labor force, the highest value of output elasticity corresponds to chemicals (1.7) and the smallest to furniture (0.98). This estimate is greater for permanent skilled workers than for temporary ones in each industrial subsector. Mineral products for unskilled temporary workers (1.87) and metal products (0.82) represent the extreme values of output elasticities. In the case of unskilled permanent workers, besides rubber and plastic whose coefficients are not statistically significant, output elasticities fluctuate between 0.85 and 1.42. This hints at a myriad of technologies and production functions across subsectors (Figure 22).

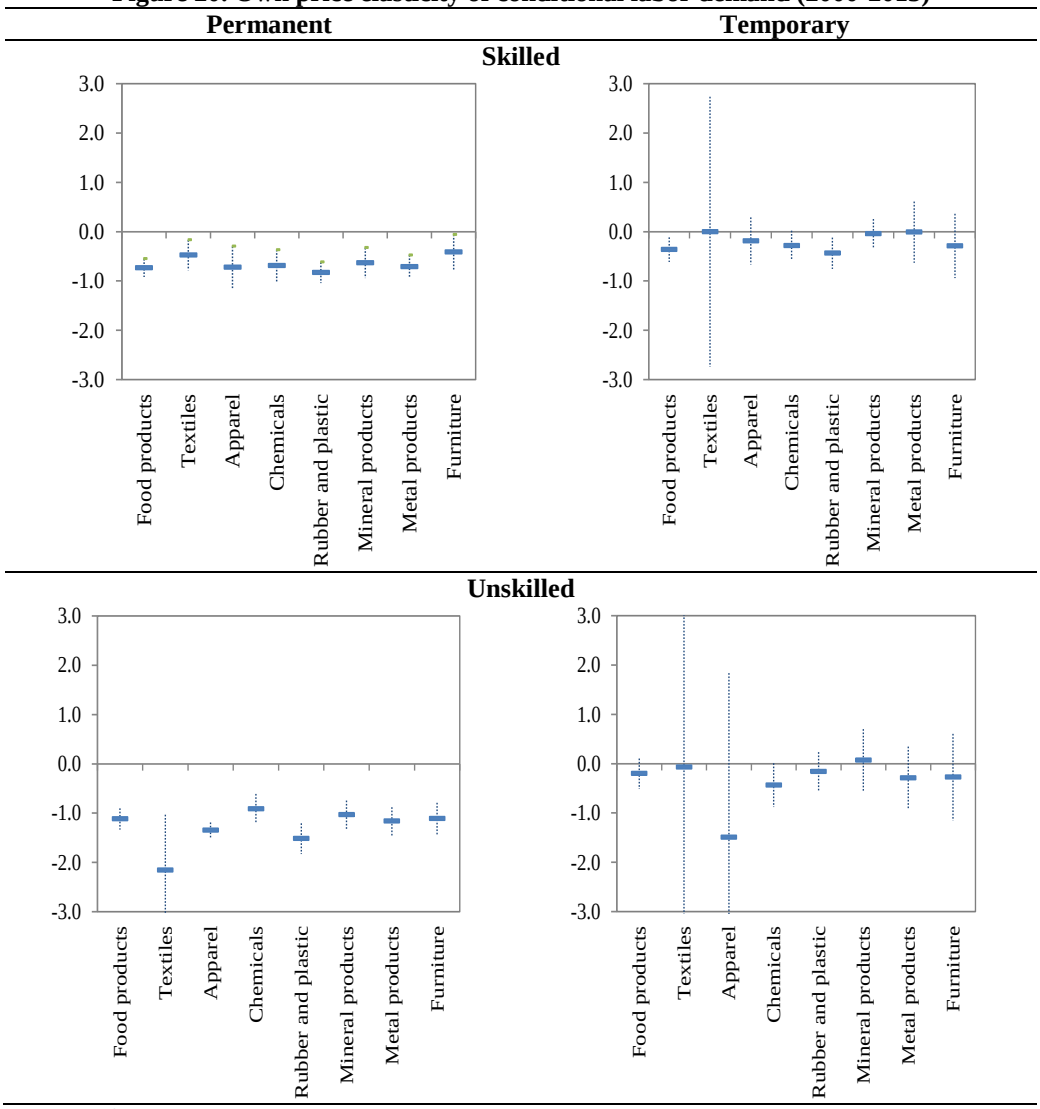
The TPF elasticity of labor demand is negative in general; when slightly positive it becomes not statistically significant. This is the case of metal (temporary skilled) and rubber and plastic

[14] Recent evidence for Colombian establishments shows that the ones that exit the market are the least productive ones (Casas, Carranza, and González, 2014).

(permanent unskilled). The TFP elasticity of permanent skilled workers fluctuates between -1.5 and -1.0 for almost all subsectors (Figure 23).

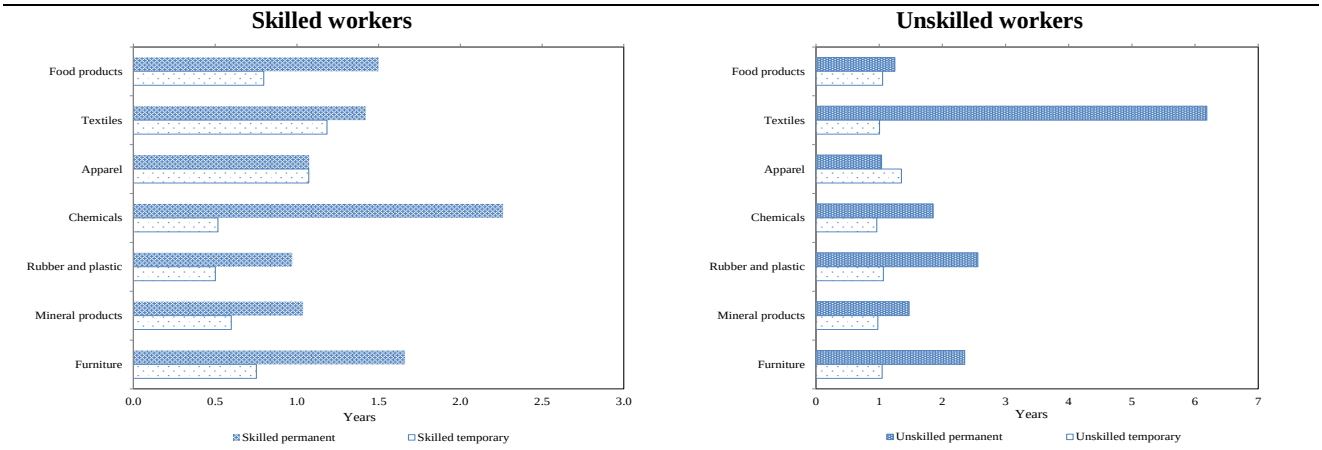
Tables 4 and 5 show the prevalence of heterogeneity across industrial subsectors. In the case of unskilled permanent workers (Table 4, upper-side), the TFP elasticity of labor demand in rubber and plastics is similar to that of food products, textiles, apparel, and chemicals subsectors. By the same fashion, the null hypothesis that chemical subsector has the same long run elasticity to TFP as mineral, metal, and furniture cannot be rejected in the case of unskilled permanent workers. As for temporary workers, the demand for unskilled labor in the textile subsector shows similarities with others (Table 5, upper-side).

Figure 20. Own price elasticity of conditional labor demand (2000-2013)



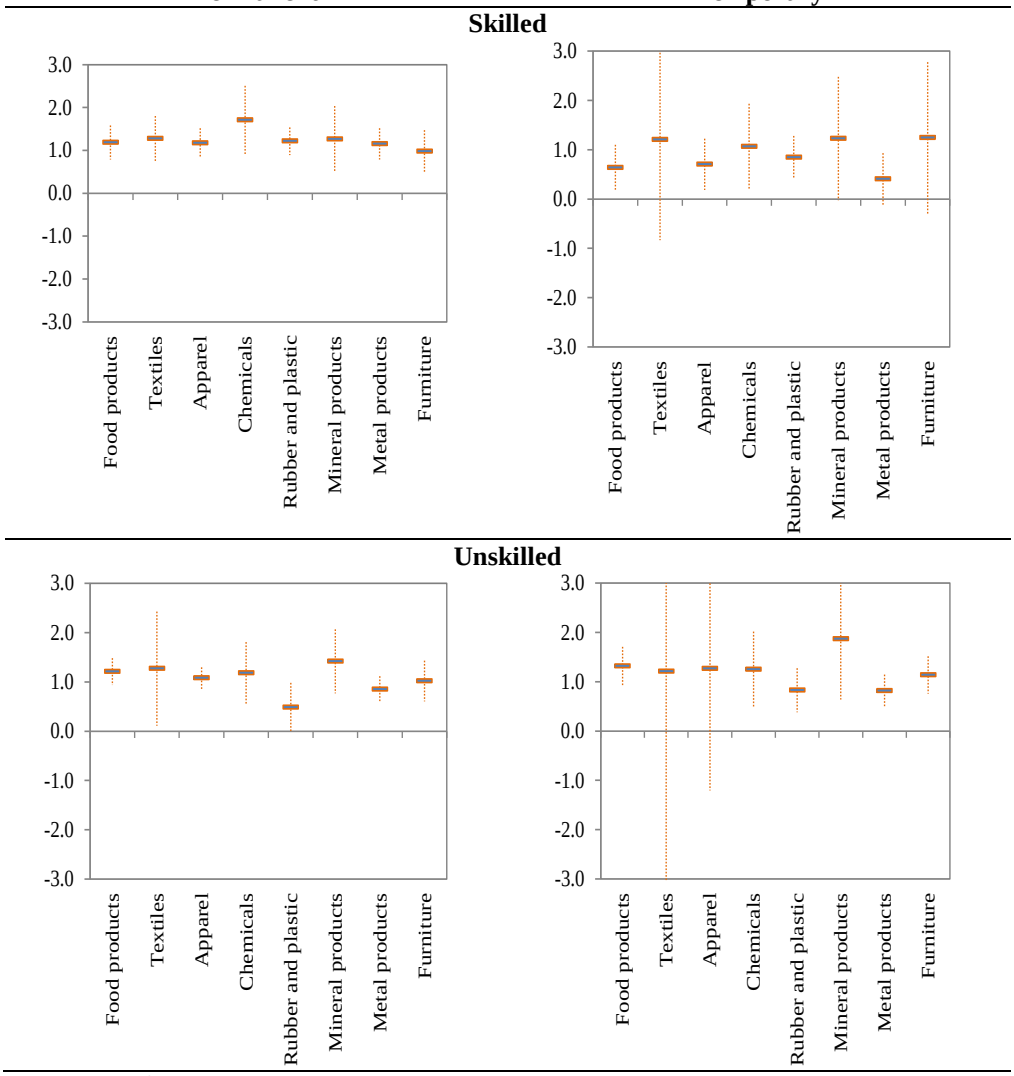
Note: 95% confidence intervals. Source: Dane-EAM; authors' calculations.

Figure 21. Halfway of labor demands adjustments of a real wage movement by subsector
Conditional labor demand



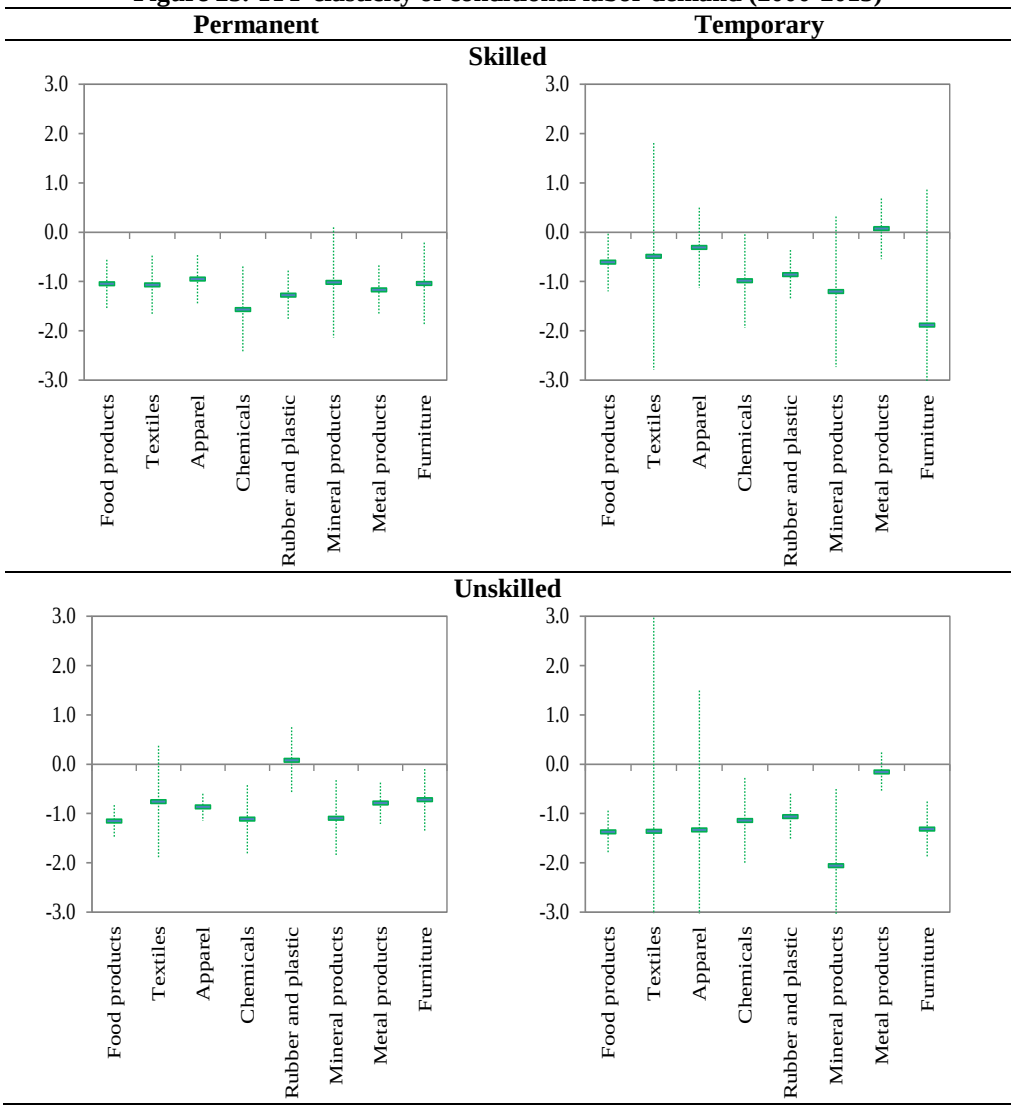
Source: Dane-EAM; authors' calculations.

Figure 22. Output elasticity of conditional labor demand (2000-2013)



Note: 95% confidence intervals. Source: Dane-EAM; authors' calculations.

Figure 23. TFP elasticity of conditional labor demand (2000-2013)



Note: 95% confidence intervals. Source: Dane-EAM; authors' calculations.

Table 4. Similarity of elasticities tests on conditional labor demand for permanent workers

Unskilled	Food products			Textiles			Apparel			Chemicals			Rubber and plastic			Mineral products			Metal products			Furniture		
Skilled	***w***	***y***	***tfp***	***w***	***y***	***tfp***	***w***	***y***	***tfp***	***w***	***y***	***tfp***	***w***	***y***	***tfp***	***w***	***y***	***tfp***	***w***	***y***	***tfp***	***w***	***y***	***tfp***
Food products															X							X		
Textiles															X						X			X
Apparel	O	O													X									
Chemicals															X			X			X			X
Rubber and plastic																								
Mineral products			O			O																		
Metal products									O															
Furniture			O			O												O						

Source: Dane-EAM; authors' calculations.

Table 5. Similarity of elasticities tests on conditional labor demand for temporary workers

Unskilled temporary	Food products			Textiles			Apparel			Chemicals			Rubber and plastic			Mineral products			Metal products			Furniture		
Skilled temporary	***w***	***y***	***tfp***	***w***	***y***	***tfp***	***w***	***y***	***tfp***	***w***	***y***	***tfp***	***w***	***y***	***tfp***	***w***	***y***	***tfp***	***w***	***y***	***tfp***	***w***	***y***	***tfp***
Food products				X	X	X		X	X															
Textiles	O							X	X		X		X			X			X			X	X	X
Apparel											X													X
Chemicals																								
Rubber and plastic																				X				
Mineral products				O	O																			
Metal products				O												O								
Furniture					O					O							O							

Source: Dane-EAM; authors' calculations.

5.3 Size heterogeneity

Another source of heterogeneity is plant sizes. Here, medium size plants employ between 11 and 50 workers, large between 51 and 500, and very large more than 500 workers. In all cases, but temporary workers (both skilled and unskilled) in very large plants, the demand for labor is well defined in the sense that elasticities are significant and with the expected signs. Demand for skilled labor is highly sensitive to output in large plants; the highest real wage elasticities are found in very large plants for skilled workers. With respect to TFP elasticities, no clear patterns emerge in either the type of workers or the size of plants. Median adjustment length is higher in very large plants and for permanent workers (Table 6).

The heterogeneity across size of plants is another property of industrial demand for labor in Colombia (Tables 7 and 8). Indeed, only with a few exceptions, all the responses to real wage, output and TFP are different depending on the type of workers and size of plants.

Table 7. Similarity of elasticities tests on conditional labor demand for permanent workers

Unskilled	Medium			Large			Very large		
Skilled	***w***	***y***	***tfp***	***w***	***y***	***tfp***	***w***	***y***	***tfp***
Medium							X		
Large									
Very large						O			

Source: Dane-EAM; authors' calculations.

Table 6. Long-run labor demand elasticities (2000-2013)

Specification	Permanent	Temporary	Permanent	Temporary
	Skilled		Unskilled	
	Medium size establishments			
Own-price	-0.514***	-0.382***	-1.008***	-0.351***
Autorregresive coefficient	0.228**	0.252***	0.469***	0.370***
Halfway of adjustment	0.469	0.503	0.915	0.697
Output	1.081***	0.769***	0.486***	0.750***
TFP	-0.983***	-0.601*	-0.353*	-0.906***
No. observations (plants)	4937	1090	8320	4533
Sargan test (p-value)	0.000	0.000	0.000	0.000
Hansen test (p-value)	0.595	0.480	0.249	0.356
Ar2 (p-value)	0.233	0.652	0.000	0.986
	Large size establishments			
Own-price	-0.722***	-0.170***	-1.150***	-0.231***
Autorregresive coefficient	0.394***	0.195***	0.547***	0.239***
Halfway of adjustment	0.744	0.424	1.149	0.484
Output	1.295***	1.087***	0.986***	0.356***
TFP	-1.105***	-0.914***	-0.863***	-0.212
No. observations (plants)	8435	3433	9850	8365
Sargan test (p-value)	0.000	0.000	0.000	0.000
Hansen test (p-value)	0.247	0.593	0.370	0.130
Ar2 (p-value)	0.954	0.806	0.536	0.089
	Very large size establishments			
Own-price	-1.106***	-0.591***	-1.018***	-0.387
Autorregresive coefficient	0.671***	0.379***	0.692***	0.522***
Halfway of adjustment	1.737	0.714	1.883	1.066
Output	1.215***	-0.055	1.503**	0.333
TFP	-1.113**	-0.029	-1.722**	0.469
No. observations (plants)	984	529	1023	1007
Sargan test (p-value)	0.000	0.000	0.000	0.000
Hansen test (p-value)	1.000	1.000	1.000	1.000
Ar2 (p-value)	0.794	0.426	0.158	0.590

Source: Dane-EAM; authors' calculations.

Table 8. Similarity of elasticities tests on conditional labor demand for temporary workers

Unskilled	Medium			Large			Very large		
Skilled	*w*	*y*	*tfp*	*w*	*y*	*tfp*	*w*	*y*	*tfp*
Medium									
Large								X	
Very large									

Source: Dane-EAM; authors' calculations.

6. Conclusions

Using the Colombian Annual Manufacturing Survey (EAM) between 2000 and 2013, this paper estimates the determinants of skill-specific labor demand accounting for heterogeneity across several dimensions.

From the descriptive statistics three noticeable aspects emerge. First, the rhythm of the employment in the manufacturing sector in Colombia seems to be governed by the paces of the four major cities: Bogotá, Barranquilla, Cali, and Medellín. Food and beverages, chemicals, apparel,

rubber and plastic, and textiles, are the most labor intensive subsectors, while large and very large plants dominate employment creation. Second, the use of temporary contracts increases remarkably overtime. This points at the quest for lower labor costs and more flexible contractual modalities; however, it creates a challenge as a larger number of temporary workers might affect establishment productivity in the long run. Temporary contracts have been associated with fewer incentives to establish solid labor relations, training, etc. (Alaimo *et al*. 2015; Pierre and Scarpetta, 2013; Addison y Texeira, 2003.) Third, the deep employment decline in the wake of the 2008-9 economic crisis links industrial employment to the demand for the goods produced by the establishments.

The paper finds that permanent (open-ended contracts) workers, both skilled and unskilled, show a higher long-run elasticity to real wage than temporary ones. This finding is in line with the substitution between temporary and permanent workers during the sample period. Skilled permanent and skilled temporary workers have lower real wage elasticities than the respective unskilled employees. Under the conditional specification of labor demand, the temporary unskilled workers show an elasticity of -0.438 and the skilled -0.256. The elasticity to the real wage of demand for unskilled workers with open-ended contracts is -1.109 and -0.682 for the skilled permanent workers.

The estimation of long-run output elasticities confirms the well-established result that labor demand is more responsive to output than to its own price. Permanent workers show elasticities of 0.949 (skilled) and 1.198 (unskilled), larger than temporaries' (0.710-skilled and 0.760-unskilled).

The results indicate that industrial labor demand determinants are quantitatively heterogeneous, across regions, subsectors and plant sizes. Shocks to the real wage affect more strongly permanent workers, in particular in cities such as Manizales and Pereira. In the case of expansions or contractions of product demand, demand for permanent skilled workers has significant responses, mainly in cities such as Pereira. Demand for temporary unskilled workers shows high output elasticities in places like Manizales, Cartagena, and Pereira. The paper also finds that larger establishments display higher responses to both output and wages.

At sector level, the demand for workers with temporary contracts exhibits the highest own-price elasticity. The response of industrial subsectors to the business cycle varies greatly and avoiding its vagaries, is just about where one works. Sectors with smaller output elasticity, like rubber and plastic, might be safe heavens during slumps, but less appealing than chemical products during expansions. However, all workers beware of Bogotá and Cali in case of technological change.

Given the conclusions reached in this paper, the design of labor market policies about minimum wage, vacancy posting, education, and vocational training should take heterogeneity into account. It is also important to form expectations about the effects of sectorial or aggregate shocks.

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