Trade Reforms, Capital Investments and the Feminization of Colombian Manufacturing Industries: 1981-2000

Reformas comerciales, inversiones en capital y feminización de las industrias manufactureras colombianas: 1981-2000

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Abstract

We exploit a natural experiment provided by the trade liberalization that occurred in Colombia at the beginning of the 1990s to see its possible effects on the gender composition of the workforce across manufacturing industries. To control for the effects of changes in capital technology, our econometric panel data strategy controls for three different types of capital stock per worker (namely, machinery, office equipment and transport equipment) and compares estimates drawn from a variety of instruments. We also control for changes in market competition within different manufacturing industries with the implementation of a concentration index variable in order to measure the degree of market power. Our findings

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point out that the Colombian manufacturing industries that became more exposed to trade flows increased their share of female employment in a more pronounced way with respect to those that remained less exposed. This effect, however, appears to be stronger in the case of highly skilled workers. As predicted by microeconomic theory, we observe lower female shares of jobs in manufacturing industries with higher levels of industry concentration. Our results are also consistent with the literature that predicts an increasing feminization of employment as a result of a the massification of emerging computer technologies since the end of the 1980s.

Keywords: Female intensity – Trade liberalization – Panel data – Colombia.

Resumen

A partir del experimento natural proporcionado por la liberalización comercial que ocurrió en Colombia a principios de la década de 1990, en este articulo analizamos hasta qué punto este fenómeno puede explicar el aumento de la participación del empleo femenino que registrado en las industrias manufactureras. Para controlar por los efectos del cambio tecnológico y la intensidad en el uso de la tecnología, nuestra estrategia de datos de panel econométricos controla tres tipos diferentes de stock de capital por trabajador (a saber, maquinaria, equipo de oficina y equipo de transporte) y compara estimaciones obtenidas mediante el uso de diferentes instrumentos. También controlamos los cambios en la competencia del mercado dentro de diferentes industrias manufactureras con la implementación de una variable de índice de concentración que mide el grado de poder de mercado. Nuestros hallazgos señalan que las industrias manufactureras colombianas que quedaron más expuestas a los flujos comerciales

aumentaron su participación en el empleo femenino de manera más pronunciada con respecto a las que permanecieron menos expuestas. Este efecto, sin embargo, parece ser más fuerte en el caso de los trabajadores altamente calificados. Como predice la teoría microeconómica, observamos una menor participación femenina en los puestos de trabajo de aquellas industrias manufactureras con niveles más altos de concentración industrial. Nuestros resultados también son consistentes con la literatura que predice una creciente feminización del empleo como resultado de la masificación de las tecnologías informáticas emergentes desde finales de la década de 1980.

Palabras clave: Feminización del empleo – liberalización comercial – datos de panel – Colombia.

1.- Introduction

Developing countries witnessed an increasing feminization of employment since the 1980s, while their economies became more open to trade. Economic policies in general, and trade liberalization in particular, have a differentiated effect on women as a result of both asymmetries in the distribution of rights over economic resources and gender-based segregated roles in the labor market economy and the household (Bahri, 2021; Pavese, 2021; Fontana, 2003). While the increasing female labor force participation can be regarded as a long-term development trend, there is also a body of literature concerned with the effects of trade liberalization on the gender composition of employment.

The economic literature offers some clues about the interactions between trade and gender differences in the labor market. According to the Stolper-Samuelson theorem within the Heckscher-Ohlin-Samuelson trade model, trade liberalization increases the demand for the most abundant factor of production. If women represent the abundant factor in exporting industries, their returns will grow faster as the expansion of exports boosts the demand for more female labor. A number of studies have explored the relationship between trade liberalization and the gender composition of employment, particularly in manufacturing industries where both employment and tariff data tend to be more accessible. Wood (1991) is one of the pioneer studies to investigate the relationship between trade liberalization and the gender composition of the labor force. He found that increasing exports in industrialized countries are strongly correlated with growing demand for female labor in developing countries. The experience from developed economies indicates that both trade and industrialization are closely interrelated to

the gender composition of economic activities. In the same vein, Goldin (quoted in Galor and Weil (1996)) explains that the necessity for fine motor skills in textiles during the industrialization in the United Kingdom and the United States, and more recently in the electronics industry in Asian economies, represent examples of absolute and comparative advantage of female over male labor along the pathway of economic development.

More recently, Gupta (2021) explored the relationship between the trade liberalization reforms in India at the beginning of the 1990s and its impact on the female share of employment. She found that firms more exposed to import competition as a result of tariff cuts tended to reduce more their female share of employment, a finding attributed to India's labor legislation that prohibits women from working long hours and overnight shifts.

Similarly, Saraçoglu et al. (2018) evaluated the changes in the share of female employment in manufacturing across a sample of 31 countries between 1995 and 2011 using structural decomposition and factor content analyses. Their findings indicate that low-technology sectors drive most of the change in the gender composition of employment in manufacturing, and that the decreasing share of female employment in low-technology sectors observed in developed and middle-income countries can be attributed to trade diversion towards China. Using also structural decomposition methods, Kucera and Tejani (2014) evaluated changes in the feminization of manufacturing employment. They found persuasive evidence in emerging and recently industrialized economies that employment refeminization has been occurring in tandem with technology intensification in manufacturing. In a more recent study (Tejani & Kucera, 2021), the same authors

concluded that technological upgrading in export-oriented industries is negatively associated with female intensity in manufacturing employment.

However, there is still a vacuum in the existing knowledge on how trade liberalization, as well as technological change, affect the gender composition of employment across manufacturing industries. As globalization is also expected to affect the competitive structure of the labor market across manufacturing industries, there are potential unaccounted implications in terms of workers' bargaining power that affect female labor intensive sectors more exposed to trade (see: Williams and Kenison, 1996, Williams, 1987, Darity and Williams, 1985).

This paper exploits a natural experiment provided by the trade liberalization that occurred in Colombia at the beginning of the 1990s to see its possible effects on the gender composition of the workforce across manufacturing industries. To control for the effects of changes in capital technology, our econometric strategy features three different types of capital stock per worker (namely, machinery, office equipment and transport equipment) and compares estimates drawn from a variety of instruments. We also control for changes in market competition within different manufacturing industries with the implementation of a concentration index variable to measure the degree of market power. We implement a number of panel data techniques including fixed-effects instrumental variables (FE-IV, hereafter) and the dynamic IV approach developed by Arellano and Bover (1995) and Blundell and Bond (1998) in order to address potential endogeneity problems on some of the regressors. Our findings point out that the Colombian manufacturing industries that became more exposed to trade flows increased

their share of female employment in a more pronounced way with respect to those that remained less exposed, particularly in the case of skilled workers in white-collar positions. As predicted by microeconomic theory, we observe lower female shares of jobs in manufacturing industries with higher levels of industry concentration. Our results are also consistent with the literature that predicts an increasing feminization of employment in response to the massification of emerging computer technologies since the end of the 1980s. The remainder of this paper is organised as follows. The second section presents the literature review and the third provides some background information for the country describing the data used for this empirical application. The fourth reports the econometric results in the light of the existing literature. The fifth and last section offers some concluding remarks.

2. Literature review

Trade theory provides some explanations for the effects of increased foreign competition on employment patterns between men and women. In particular, the Stolper-Samuelson theorem within the Heckscher-Ohlin-Samuelson trade model indicates that trade liberalization increases the demand for, and the returns to, the most abundant factor of production. Thus, if women constitute the abundant factor in exporting industries boosted by trade, it is possible that their returns will grow faster than those of male workers and, in this way, the gender wage gap will be reduced. Wood (1991) provides one of the first studies to survey the relationship between trade and the gender composition of the labor force in developing countries. The author investigated the effects of trade on female employment ratios in manufacturing for a sample of countries and found that increasing exports to industrialized economies are associated with higher relative

demand for female intensive goods from developing countries. But at the same time, Wood (1991) found that trade flows of manufacturing goods from the 'South', which to a great extent are intensive in female labor, were not associated with reductions in relative demand for female labor in manufacturing industries from developed countries.

Several recent papers address the relationship between trade liberalization and the gender composition of employment, particularly in the manufacturing sector. Gupta (2021) explored the association between the trade liberalization that took place in India at the beginning of the 1990s and the female share of employment, using a panel of 1,289 manufacturing establishments surveyed in 1989 and 1998, and census data to construct another panel of employment by gender at the district level for the years 1991 and 2001. She concludes that trade liberalization worsened labor inequalities in India as tariff reductions are found to be associated with decreasing shares of female employment across manufacturing industries, a result explained by India's labor legislation that prohibits women from working night shifts and extended hours. This result was also more pronounced among establishments characterized by high levels of labor intensity and in states where labor legislation makes more difficult the dismissal of workers.

In a similar way, Saraçoglu et al. (2018) studied the changes in employment feminization in manufacturing across a sample of 31 countries between 1995 and 2011 using structural decomposition and factor content analyses. They find that the defeminization of employment documented for low-technology industries from developed countries in the earlier literature is also taking place in developing countries since the 1990s, particularly in the case of middle-income

economies, mainly because of trade diversion towards China. Although the female shares of employment in mid and high-technology sectors improved modestly in both developed and middle-income countries, trade flows appear to reduce the overall participation of women in the manufacturing employment structure in that part of the world. Their results also indicate that as countries transform their manufacturing industries from labor-intensive/low-technology activities to capital-intensive/high-technology industries, labor defeminization intensifies, and trade liberalization appears to reinforce such trend.

Using also structural decomposition methods, Kucera and Tejani (2014) evaluated changes in the feminization of manufacturing employment across a sample of 36 countries between 1981 and 2008. They find persuasive evidence in emerging and recently industrialized economies that employment defeminization has been occurring in tandem with technology intensification in manufacturing, particularly in the case of labor-intensive sectors such as textiles and apparel. Most of the changes in the gender composition across manufacturing industries took place within the most labor-intensive groups, while employment reallocation effects did not play a major role. Kucera and Tejani (2014) also conclude that defeminization of manufacturing in East Asian economies is consistent with an increasing preference for highly skilled male workers as the introduction of sophisticated technologies intensifies.

In a more recent study, Tejani & Kucera (2021) examined the effects of technological change and structural transformation in a sample of 14 countries characterized by the predominance of export-oriented and labor-intensive manufacturing industries. They confirm that technological

upgrading is strongly associated with defeminization of manufacturing employment while within-industry effects appear more important to explain changes in female intensity of labor than employment reallocation effects. The largest shifts in the gender composition of employment were found in the manufacturing sectors of food, beverages, and tobacco; textiles; leather products and footwear, and motor vehicles, in which improvements in labor productivity were found associated with reductions in female employment intensity.

Banerjee & Veeramani (2017) analysed the effects of trade policy on female employment intensity in the case of India using a panel of manufacturing industries between 1998 and 2011. They conclude that lower import tariffs are positively associated with female employment intensity, a finding that they attribute to a cost-cutting strategy whereby competitive firms substitute male workers with cheaper but equally productive female workers. The authors find also that the intensification in the use of technology reduces the proportion of women in the workforce. These two effects acted one against another in a way that female employment gains as a result of trade liberalization have remained modest in the case of India.

From a theoretical point of view, trade liberalization has the potential to affect the gender composition of employment in at least four different ways. First, as long as women and men are imperfect substitutes in production, increased trade may affect the relative demand (as well as relative wages) of one gender group with respect to another. New opportunities arising from increasing exports, as well as more competition from imported goods, have the potential for both changing gender differences in the labor market if women are concentrated in sectors more exposed to trade (Collier, 1994).

Second, trade liberalization reduces the relative prices of capital goods and imported technology in the case of developing countries. This might open new employment opportunities for women as physical strength becomes less relevant. Some studies indicate strong complementarities between female labor and a technology intensification (Galor and Weil, 1996, Weinberg, 2000, Welch, 2000).

Third, the "taste for discrimination hypothesis" formulated by Becker (1957) suggests that policy measures to increase competition are likely to reduce labor market discrimination against women and other minorities. Thus, increasing competition from imports as a result of trade liberalization is likely to reduce the scope for non-competitive behavior in the form of discrimination (Artecona and Cunningham, 2002, Black and Brainerd, 2004).

Fourth and lastly, more competitive markets resulting from trade liberalization might also weaken the bargaining position of women in female-intensive industries as local firms respond to increasing imports with cost-cutting strategies to reduce labor costs. If women are concentrated in manufacturing sectors more exposed to trade in developing countries such as textiles, clothing, electronics, and garment, it is possible that trade liberalization worsens the conditions for female employment (see: Williams and Kenison, 1996, Williams, 1987, Darity and Williams, 1985).

The previous four theoretical considerations inspire the empirical strategy that will be presented in the rest of this paper. They imply that the gender composition of employment can be affected not only by changes in trade flows of manufacturing goods, but also by the intensification in the

use of technology as well as by the competitive forces that impact the labor market.

3. Background and data: trade liberalization and labor markets in Colombia

3.1 Female share of jobs in manufacturing industries

The dependent variable in this empirical analysis is the female share of jobs in manufacturing industries. This variable was estimated with microdata from the Annual Manufacturing Survey -AMS for the period 1981-2000 at the three-digit level of the International Standard Classification of Industries -ISIC, Revision 2[1]. A number of methodological adjustments, including a change to the ISIC Rev.3, rendered impossible the incorporation of more recent years in this analysis.

Estimates at the aggregate of Colombian manufacturing industries indicate that the share of female jobs rose from 31.2 to 36.3 percent between 1981 and 2000 (see Figure 1, panel a). Demographic change a comparatively better improvements in educational achievement among women are referred in the Colombian literature as the main drivers from the supply side of the labor market that explain the incorporation of an increasing proportion of women in the labor market (Isaza-Castro, 2002; Isaza-Castro, 2006; Isaza-Castro et al., 2007; Arango and Posada, 2002; Tenjo and Ribero, 1998; Santa María and Rojas, 2001; Tenjo and Ribero, 1998). It is worth to mention that the total number

1 The AMS could be considered as a census in the sense that it is gathered annually amongst nearly all manufacturing establishments with more than ten workers since 1975. This survey is administered by the National Statistical Administrative Department (DANE, from its initials in Spanish). For more information about AMS microdata, see: https://www.dane.gov.co/index.php/estadisticas-por-tema/industria/encuesta-anual-manufacturera-enam -last access: July 3, 2022.

of jobs in Colombian manufacturing industries reached the lowest level by the end of the analyzed period among blue-collar workers of both sexes and white-collar male workers, while white-collar female workers stand as the only group to increase the number of jobs between 1981 and 2000. The same estimates show that the proportion of female jobs amongst white-collar workers has been higher than in the case of blue-collar workers over all years reviewed in this study (see Figure 1, panel b)[2].

The contraction of manufacturing employment growth in Colombia could be attributed to a number of factors including an increased exit rate of plants after the introduction of trade liberalization reforms in 1990 (Eslava et al., 2009), weaker demand for Colombian manufactured goods internally due to a severe economic downturn at the end of the 1990s, as well as a less competitive position of Colombian manufacturing exports due to the appreciation of the Colombian currency for most of that decade (Ocampo et al., 2004). Goldberg and Pavcnik (2003) claim that labor market rigidities (rather than trade liberalization) were also a major factor contributing to both the informalization of urban employment and the stagnation of formal employment in manufacturing firms over the 1990s.

The increase in the share of female jobs commented above was the highest amongst white collar workers as it rose from 31.7 per cent in 1981 to 45.5 per cent in 2000, while in the case of blue-collar workers there was a more modest rise, from 29.8 to 32.6 per cent over the same years (see Figure 1,

2 The characterization of the labor force between white and blue-collar workers just commented above was dictated by the availability of questions in the survey over the entire period of analysis. Other alternatives of analysis, namely, by skill, hierarchical, and contractual status for the whole period from 1981 to 2000 were not feasible due to changes in the questionnaire.

panel b). Such trends are in line with some of the literature reviewed above, according to which the feminization of the labor force is concomitant with the process of economic development.

Employment in Colombian manufacturing industries also experienced a structural transformation in terms of the skill composition of the workforce over the years analyzed here as the percentage of white-collar jobs rose from 24.6 per cent in 1981 to 32,3 per cent in 2000. It should be noted that this increase has been more pronounced amongst women (see Figure 2). These trends suggest a structural transformation of the manufacturing employment by skill level in Colombia where the increasing proportion of white-collar workers is benefiting the incorporation of more women into the manufacturing workforce. This interpretation is in tandem with Galor and Weil (1996) and Welch (2000) who conclude that the incorporation of technology in production processes requires the demand of both skilled workers and female labor.

3.2 Tariffs and trade

Trade liberalization in Colombia revolved around two elements. First, the signing of trade agreements with México, Chile, and the Andean countries of Venezuela, Ecuador, Peru, and Bolivia. Second, the reduction of tariffs and non-tariff barriers to trade in 1990 with the initial idea of a gradual approach over a time horizon of more than three years. According to Attanasio et al. (2004), Goldberg and Pavcnik (2005b, 2005a) and Jaramillo and Tovar (2006), the fact that Colombia did not participate in the GATT negotiations for the reduction of trade tariffs made this reform comparatively more drastic than in many other developing countries. On top of all of that, Colombian economic authorities decided to

speed up the liberalization process in view of macroeconomic circumstances such as high inflation, a dramatic increase in the inflow of foreign capital, and a reduction in trade flows. Thus, the initial liberalization schedule for 1994 in terms of non-tariff barriers and import tariffs was completed by the end of 1991 (Edwards, 2001).

We measure the degree of trade openness in Colombia with simple and weighted average import tariffs across 29 manufacturing industries (see Figure 3). According to weighted average estimates, import tariffs for all manufacturing industries fell from 16.9 per cent in 1981-1984 to 6.4 per cent in 1997-2000[3]. The largest reductions on weighted tariffs over these years (all of which were more than 20 percentage points) were reported on 356- Plastic products, 313- Beverage industries, 384- Transport equipment, 381- Fabricated metal products and, 332- Furniture and fixtures. Some of the existing literature for this country suggest that the most protected industries before trade liberalization were also the sectors with the highest concentration of skilled workers and thus, experienced the largest reductions in tariffs during the liberalization period (Attanasio et al., 2004, Goldberg and Pavcnik, 2003, Goldberg and Pavcnik, 2005b, Goldberg and Pavcnik, 2005a, Jaramillo and Tovar, 2006).

3.3 Concentration, market power and trade reforms

As explained above, trade liberalization is expected to bring about more competition in the form of increased imports and, thus, reduce the scope for inefficient gender discrimination. Competition from imports, however, may also strengthen the bargaining position of local firms as they

3 Weights are based on imports value in US dollars.

are forced to implement cost-cutting strategies to survive and remain competitive while workers face more limited employment options within industries more exposed to trade.

We computed a four-firm concentration ratio (CR_4) across industries to control for changes of market structure, based on the ratio between the gross product value from the four largest firms within a given industry and the total gross product value for the same industry, according to the following expression:

$$CR_4 = \sum_{i=1}^{4} S_i \tag{1}$$

where S_i indicates the gross product share of the i firm in the total gross product of a given manufacturing industry. Results for this index show a modest reduction in market concentration along the two decades defined in this study, from an average of 0.452 in 1981 to 0.439 in 2000. Figure 4 shows this concentration ratio for each one of the 29 ISIC sectors along the years defined in this study on an identical scale to display the high degree of stability in the ranking of the most (and less) concentrated sectors. The most concentrated sectors in which the top four firms represents more than 70% of the production value are 353- *Petroleum refineries*, 314- *Tobacco manufactures*, 354- *Products of petroleum and coal*, 372- *Non-ferrous metal basic industries*, 355- *Rubber products* and, 361- *Pottery, china and earthenware*. In contrast, the least concentrated industries over the years reviewed with an index below 20 per cent are 311- *Food products*, 381- *Fabricated metal products* and, 322- *Wearing apparel, except footwear.*

3.4 Capital equipment

Increasing availability of capital equipment in manufacturing industries enables female labor intensity as it makes physical strength less relevant (Galor and Weil, 1996). Since trade liberalization makes cheaper the access to imported capital equipment, there is a possibility of interaction of this variable with the participation of women in the workforce. To account for this, we estimated the natural logarithm of the amount of capital per worker in manufacturing industries (in Colombian pesos at constant prices for 1999) under three different categories: machinery equipment, transport equipment, and office equipment. This capital stock measure was estimated according to the following formula for perpetual inventories:

$$K_{it} = K_{it-1} + I_{it} + (K_{it-1} + I_{it}) \times D_i \qquad (2)$$

where K represents the capital stock of industry l at the beginning of year t, I depicts the gross investment of industry i and, D represents the observed depreciation rate of industry i calculated by Pombo (1999) according to the ISIC Rev. 2, at the 3-digit level. As in the case of our dependent variable, estimates for K and D were obtained also from microdata of the AMS from 1981 to 2000.

Figure 5 presents the estimates of the logarithm of capital stock per worker according to expression (2) for the 29 manufacturing sectors over the 20 years span covered in this analysis. All manufacturing industries reported an increase in the amount of capital per worker for both machinery and office equipment between 1981 and 2000, while the amount of transport equipment rose only in 14 out of the 29 manufacturing sectors over the same years. The largest

increases in the amount of capital per worker were reported by 313- *Beverage industries*, 362- *Glass and glass products*, a supplier sector of the former, 361- *Pottery, china and earthenware*, and 369- *Other non-metallic mineral products*.

4. Econometric analysis

4.1 Methodology

In this empirical application, we implement a variety of panel data models to explain the effects of trade policy on the gender composition of the labor force across manufacturing industries[4]. These include fixed-effects instrumental variables (FE-IV) estimators, and the dynamic instrumental variables -IV approach developed by Arellano and Bover (1995) and Blundell and Bond (1998). As technological changes may also affect the share of female jobs over time, our empirical strategy also incorporates the three explanatory variables for the (natural logarithm of) capital stock per worker in terms of machinery, transport, and office equipment. As anticipated above, we also control for changes in market structure with

4 Other of studies have assessed the impact of trade liberalization on the extent of gender wage discrimination, rather than the gender composition of employment (see, for instance, Artecona & Cunningham 2002 in the case of Mexico; Reilly and Vaseudeva 2005, and Chamarbaguala 2006 in the case of India). Such studies use household survey microdata that allows the estimation of wages by gender based on information from the supply side of the labor market. Our study is based on survey data gathered from the demand side of the labor market, this is, from firms rather than households. In particular, we are using data from the Annual Manufacturing Survey -AMS of Colombia which do not provide disaggregated information for men and women about wages or labor costs. Other variables, such as the number of female and male workers are recorded with a high degree of precision in this survey, and this is precisely the information that we use in the present empirical application to construct the dependent variable in our econometric models. Given that the unit of information in the AMS is the firm and not the worker (as it would be in the case of household surveys), other conventional variables in studies of gender wage discrimination such as schooling levels or professional experience cannot be accounted for in the present empirical application.

the inclusion of a concentration index based on expression (1) in Section 3.3, above.

We implemented a FE-IV approach based on an individual industry effects model

$$y_{it} = \alpha_i + x'_{it}\beta + \varepsilon_{it} \tag{3}$$

where the dependent variable, y_{it}, is the share of female jobs in industry i at time t, x'_{it} depicts a set of explanatory variables (in this case, a trade variable, a concentration index and, a capital stock per worker measure in logs – either machinery, transport or office equipment) and β represents a vector of coefficients to be estimated. The structure of the error component, in addition to the conventional random component ε_{it}, assumes the existence of unobserved time-invariant industry fixed effects denoted by α_i. With the availability of appropriate instruments, z_{it}, it is possible to obtain consistent estimation of β in cases where x_{it} is correlated with the time-invariant error component α_i. The validity of such instruments requires that they are uncorrelated to the idiosyncratic error ε_{it} so,

$$\mathrm{E}(\varepsilon_{it}|\alpha_i, z_{i1}, \ldots, z_{it}, \ldots, z_{iT}) = 0 \tag{4}$$

Thus, FE-IV estimates are consistent if assumption (4) is satisfied. As customary in panel data, the condition of the idiosyncratic error term $\varepsilon_{it} \sim (0, \sigma^2_{\varepsilon})$ is frequently not satisfied due to serial correlation within panel units. For this reason, we estimated heteroscedasticity-robust standard errors that allow for intergroup correlation with the implementation of a clustered sandwich estimator to adjust the variance-co

variance matrix[5]. FE-IV estimates presented here with cluster-robust standard errors were calculated with the ***xtivreg2*** Stata command written by Schaffer and Stillman (2010), while in models without instruments were calculated with the conventional ***xtreg*** Stata command.

In addition, we compare the previous estimates with those from a dynamic panel data system obtained through the Generalized Method of Moments -GMM developed by Arellano and Bover (1995) and Blundell and Bond (1998). This approach relies on a simultaneous estimation of a system with two equations, one in differences and one in differences, with a set of instruments used in each equation.

The model can be represented by the following expression:

$$y_{it} = \delta y_{i,t-1} + x'_{i,t}\beta + \rho_i + \varepsilon_{i,t} \tag{5}$$

in which $\delta y_{i,t-1}$) is the lagged dependent variable and its coefficient, p_i represents the industry fixed effects and, $\varepsilon_{i,t}$ is an *i.i.d.* error term. First differencing of (5) eliminates p_i as follows,

$$y_{i,t} - y_{i,t-1} = \delta(y_{i,t-1} - y_{i,t-2}) + \beta(x_{i,t} - x_{i,t-1}) + (\varepsilon_{i,t} - \varepsilon_{i,t-1}) \tag{6}$$

Under this specification, the choice of instruments is performed under the less restrictive assumption of *weak*

5 Chapter 8 in Angrist and Pischke (2008) describe this and other procedures for robust covariance matrix estimation in panel data. See also Cameron and Trivedi (2009) for a review of different estimates for the variance-covariance matrix including the cluster-robust procedure.

exogeneity[6]. However, this estimator is characterized by both low asymptotic precision and small sample biases. For this reason, Blundell and Bond (1998) advice that this estimator should be complemented with the regression equation in levels. Moreover, when the lagged dependent and explanatory variables are persistent over time they represent weak instruments for the regression equation in differences (Blundell and Bond, 1998). According to Griliches and Hausman (1986), another problem is that the differences estimator is biased due to decreasing signal-to-noise ratios. For all of this, Arellano and Bover (1995) system estimator reduces potential biases by the simultaneous estimation of equations (5) and (6). Industry-specific effects are instrumented with lagged differences which, in the context of the regression in levels, represent adequate instruments. Although industry-specific effects may be correlated with right-hand side variables, there is no correlation between them when they are expressed in differences.

Consistency of this GMM estimator relies on whether the lagged explanatory variables are adequate instruments. Following Arellano and Bond (1991) and Arellano and Bover (1995), we tests the validity of instruments with both the Sargan test for over-identifying restrictions and the second-order serial correlation test. The Sargan test statistic is:

$$s = \hat{\epsilon}' Z(\frac{1}{N}\sum_{i=1}^{N} Z_i'\hat{\epsilon}_i\hat{\epsilon}_i' Z_i)^{-1} Z_i'\hat{\epsilon} \qquad (12)$$

6 Under the two assumptions of (i) no serial autocorrelation in the residuals and, (ii) weak exogeneity, the two following moment conditions apply:

$$\mathrm{E}[y_{i,t-\dot{s}}(\varepsilon_{i,t} - \varepsilon_{i,t-1})] = 0 \quad \forall \quad s \geqslant 2; t = 3, \ldots, T \qquad \text{(i)}$$

$$\mathrm{E}[x_{i,t-\dot{s}}(\varepsilon_{i,t} - \varepsilon_{i,t-1})] = 0 \quad \forall \quad s \geqslant 2; t = 3, \ldots, T \qquad \text{(ii)}$$

These two conditions represent the basis for the GMM estimator of differences.

where S follows a x^2_{m-r} distribution where $m-r$ is the number of instruments minus the number of exogenous variables, ε_{jt} represents the estimated residuals and Z depicts a set of valid instruments in the differenced equation. The Sargan test assesses the sample analogue of the moment conditions used in the estimation process in which failure to reject the null hypothesis gives support to our model.

The second test checks the no serial correlation hypothesis in the error term by examining first and second order serial correlation in the residuals from the regression in differences. According to Arellano and Bond (1991) and Arellano and Bover (1995), failure to reject the null hypothesis of no second-order serial correlation leads to conclude that the original error term is serially uncorrelated.

4.2 Results

Table 1 presents the definition of the variables included in the models just explained above while Table 2 reports their panel summary statistics. This is a balanced panel with no missing values in which all variables fluctuate within the range of 0 and 1, except in the case of the three stock of capital per worker variables as these are expressed in natural logarithms of Colombian pesos at 1999 constant prices. For all variables excluding the stock of office equipment per worker variable *(lnkpw_office)*, most of the variance takes place between manufacturing industries rather than within manufacturing industries.

We implement the FE-IV approach described in expression (3) in order to explain changes in the female intensity of employment as a result of trade liberalization. For this purpose, we incorporate two trade flow measures, the import

penetration coefficient *ipc* and the export orientation coefficient *eoc*, in addition to the concentration index *(CIGP)* described in section 3.3, and the three capital stock measures per worker for machinery, transport, and office equipment (*lnkpw_mach, lnkpw_trans and, lnkpw_office* –see Table 1 for definitions). Under this framework, we found that both trade measures, as well as the concentration index variable *(CIGP)*, are endogenous regressors based on a version of the Hausman test for endogenous regressors developed in Stata™ by Schaffer and Stillman (2010) that is robust to violations of conditional homoskedasticity[7]. Thus, we instrumented *CIGP* with the logarithm of the number of firms, *ipc* with average tariffs (see section 3.2, above) and, *eoc* with a conventional relative trade balance measure *(RTB)* constructed as follows:

$$RTB_{it} = \frac{x_{it} - M_{it}}{x_{it} + M_{it}} \tag{13}$$

where X_{it} and M_{it} denote the exports and imports, respectively, from industry *i* at time *t*.

We believe that the use of these instruments is justified not only on their theoretical validity but also in view of their high correlation with the endogenous variables, as we demonstrate below. In the case of the import penetration, we argue that average tariffs represent an appropriate instrument measure of trade policy as they are aimed at moderating import flows. Several empirical applications dealing with the effects of trade on labor market outcomes in Colombia have directly relied on tariffs as a proxy measure of trade policy (Attanasio et al.,

7 The results for this test presented in the Statistical Appendix of this paper (see Tables A1 and A2) indicate that the null hypothesis that a given set of regressors is exogenous can be safely rejected in the case of the variables already indicated: *CIGP, ipc* and *eoc*. See notes at Tables A1 and A2 for details on the structure of this test.

2004, Goldberg and Pavcnik, 2003, Goldberg and Pavcnik, 2005b, Jaramillo and Tovar, 2006)[8]. We believe, however, that using tariffs instead of import penetration as a variable to control for the impact of trade policy on the labor market is problematic as it omits the effects of other trade barriers such as import licenses and import quotas. Contrastingly, import penetration provides an outcome measure of the effects of trade policy on the competitive environment in which local firms have to operate. Tariffs, on the other hand, provide a good instrument for import penetration as they embody a trade policy measure aimed specifically at moderating import flows into the domestic economy. Regarding the export orientation coefficient, we believe that the relative trade balance measure described in expression (5) represents a reasonable estimate of the competitive position of manufacturing industries with rich variation across sectors and over time. We also instrument the concentration index of gross product (CIGP) variable with the natural logarithm of the corresponding number of firms for each combination of industries and years based on the assumption that more competitive industries (i.e., with a lower concentration index) have, on average, a larger number of firms.

In Table 3 we formally test the association between the endogenous regressors, and the selected instruments incorporated in subsequent FE-IV models presented below. According to these results, we can reasonably be confident that our instruments are highly correlated with the endogenous regressors not only in terms of the FE within estimator (see Columns 1, 3 and 5) but also in terms of the first-differences

8 On these papers, Attanasio et al (2004) use tariffs at the beginning of the 1980s interacted world coffee prices as instruments for tariffs while Goldberg and Pavcnik (2005b) perform an identical strategy. Jaramillo and Tovar (2006) also use tariffs at the beginning of the 1980s interacted with annual exchange rates.

specification (see Columns 2, 4 and 6). As in other models presented along this paper, the standard errors reported in Table 3 are robust for cluster correlation. On these results we verify a negative association between import penetration *(ipc)* and average tariffs *(a_tariffs)* as can be seen in the regression coefficients in Columns 1 and 2 which are statistically significant at the one per cent level in the case of the FE estimator and, at the five percent level in the case of the first-differences estimator. We confirm also a negative association between the concentration index of gross product *(CIGP)* and the natural logarithm of the number of plants *(ln_noplants)* as can be inferred from the estimated coefficients in Columns 3 and 4 of Table 5. Lastly, we corroborate a positive relationship with statistically significant coefficients at the one per cent level between export orientation *(eoc)* and the relative trade balance measure *(rtb)* presented in expression (5), above.

Results for our FE-IV estimates for the effects of import penetration on the female share of jobs are presented in Table 4. In order to check the robustness of our FE-IV estimates, we also calculate the same female share equations with instruments derived from their lagged values. Standard errors for FE-IV models presented on Table 4 are robust for cluster serial autocorrelation. To further check these results, we also report estimates using the Generalised Method of Moments approach developed by Arellano and Bover (1995) and Blundell and Bond (1998) (see Section 4.1, above). These estimates display the import penetration coefficient -*ipc* as a control for the degree of trade openness (while those on Table 5 use the export orientation coefficient for this purpose). The results indicate that the import penetration coefficient is positively associated with the female share of jobs in manufacturing industries particularly in the case of white-collar workers, with statistically significant coefficients

under all specifications[9]. Results for all workers confirm this result although they turn statistically insignificant under the dynamic panel data system (column 4) while the coefficients for blue-collar workers are statistically insignificant under the FE-IV and the AB/BB estimators.

The strong association between import penetration and the proportion of female workers among white-collar positions is in accordance with Banerjee & Veeramani (2017) who also found that lower barriers to trade are positively associated with female employment intensity. Saraçoglu et al. (2018) also found modest improvements in female employment intensity in the case of mid and high-technology sectors as a result of trade liberalization, although the effect was the opposite for low-skill employment.

The Concentration Index of Gross Product -CIGP appears negatively associated for all workers under all estimation techniques analyzed here, with coefficients statistically significant beyond conventional levels. However, the disaggregation by skill level reveal that this statistical significance remains only in the case of the dynamic AB/BB estimator which suggest a stronger negative effect that is about four times higher among white-collar workers than among blue-collar workers.

The same results in Table 4 also indicate a positive association between the feminization of manufacturing employment and two of the three capital per worker variables (in logs), machinery and office equipment, while the transport equip-

9 Table A3 in the Statistical Appendix reports the two tests outlined in section 4.1 for the validity of the instruments used in the dynamic panel data model presented in Column 4 of Tables 4 and 5. According to the Sargan test for over-identifying restrictions we find evidence that the instruments are exogenous. Likewise, the results for the second-order serial correlation test suggest that the residuals from the regression in differences are serially uncorrelated.

ment variable appears negatively correlated. The coefficients for these variables, however, are not statically different from zero in a number of cases except in the case of the office equipment variable *(lnkpw_office)* among white-collar workers. This suggests the existence of complementarities between the feminization of manufacturing labor and the intensification in the use of computing equipment in the Colombian manufacturing industries that benefited, mostly, the skilled segment of the female labor force. This result is consistent with the hypothesis supported by some of the studies reviewed above (Galor and Weil, 1996, Weinberg, 2000, Welch, 2000) which suggest that women enjoy a comparative advantage in cognitive skills. This interpretation is, to some extent, in line with the formulation proposed by Weinberg (2000) who argues that, in the case of the United States, a substitution process between highly skilled women and less skilled men might be explained by the increase in computers use which, on the margin, tends to favor the former. Figures presented in Figure 1a, above, suggest that this phenomenon might also be happening in Colombian manufacturing industries as female *white-collar workers* were the only group of the labor force which shows an absolute increase of employment levels between 1981 and 2000. Contrastingly, male *blue-collar workers* were the group with the largest reduction in manufacturing employment over these years in both absolute and relative terms.

The econometric results presented in Table 5 are intended to investigate the effects of an alternative trade variable, the export orientation coefficient –*eoc*. In this case, increased levels of trade in the form of export orientation are positively associated with the proportion of women in manufacturing employment. Nevertheless, the coefficients are statistically insignificant in several cases. Only in the case of blue-co-

llar workers, we find a statistically significant association between *eoc* and the dependent variable in the case of the FE-IV estimator based on lagged values of the endogenous regressor (column 3) and the dynamic panel data estimator (column 4). In the case of white-collar workers, all estimators are statistically significant except in the case of the dynamic panel data (column 4).

The results in Table 5 also corroborate the effects of other variables on the female share of jobs in manufacturing industries. In the case of our market concentration variable *(CIGP)*, there is strong evidence of its negative association with the female share of jobs for all labor force groupings analyzed here. Coefficients for this variable are well determined in most cases although they tend to decrease in significance in the case of the FE-IV estimator based on lagged values of the endogenous regressor (column 3). Regarding the capital investment variables, they confirm our previous findings of a well determined positive association between purchases of office equipment and the female share of white-collar manufacturing jobs under all four specifications. We also verify a negative association between transport equipment and the dependent variable but the coefficients for this variable decreased its statistical significance when they are disaggregated by white and blue-collar jobs.

The positive effects of both trade openness and the intensification in the use of office equipment on the feminization of employment in the manufacturing industries of Colombia are in line with the segregation dimension implicit in Becker's hypothesis of labor market discrimination. In other words, increased levels of market competition erode monopolistic rents to discriminate against women. Although we do not have any evidence of reduced gender discrimination, we do

observe that more competitive industries tend to have on average and *ceteris paribus*, higher female shares of jobs. At least, this is what we would expect according to Becker's hypothesis in terms of the gender composition of the labor force because of increasing competition.

5. Concluding remarks

This paper provides new evidence on the relationship between trade reforms and employment outcomes by gender with an empirical application to Colombian manufacturing industries. Although the evidence presented in this paper does not formally test whether women are more (or less) discriminated in the labor market, our empirical results suggests that trade liberalization, as well as some of the structural transformations in terms of the degree of market competition are associated to the feminization of employment in Colombian manufacturing industries.

We found convincing evidence that increased levels of import penetration are positively associated with higher female shares of jobs in manufacturing industries. Different econometric techniques presented in this paper point towards a similar conclusion, and they indicate that this effect was probably stronger amongst *white-collar workers*. Our estimates using the export orientation coefficient variable point to a similar conclusion, although the statistical significance in this case is less robust. Such complementarities between trade openness and labor feminization are also found in the case of India by Banerjee & Veeramani (2017) and for a sample of 31 countries across the world between 1995 and 2011 by Saraçoglu et al. (2018) in the case of high-technology sectors. Our results are, however, in contrast with those of Saraçoglu et al. (2018) who found that trade was associated

with defeminization of labor in the mid and low/technology sectors in India, a conclusion also verified by Gupta (2021).

On the other hand, we found persuasive evidence that higher levels of market concentration are negatively associated with the female share of jobs in the manufacturing industries of Colombia, indicating that, ceteris paribus, more competitive environments are more likely to incorporate larger shares of female employment. So far, this is what we expected to find from the existing literature in relation to the segregation dimension implicit in Becker's hypothesis of labor market discrimination. As our dependent variable is the female share of jobs, we remain agnostic as to whether the effects of increased competition, either in the form of increased international trade or lower market concentration, have any effect on the extent of gender pay discrimination. We should stress that increasing levels of female employment in manufacturing industries could occur with or without improvements in the bargaining position of women in the labor market.

We could also verify some complementarities between female labor and the use of some types of capital equipment. Our estimates under different panel data techniques are suggestive that the increasing use of office equipment is concomitant with higher shares of female employment in manufacturing industries of urban Colombia. These findings support the hypothesis that the increasing use of technology favors the incursion of women in the labor market as they enjoy a comparative advantage in cognitive skills (Galor and Weil, 1996, Weinberg, 2000, Welch, 2000). Such conclusion is consistent with the fact that the presumably positive effect derived from the increasing use of office equipment is confined to the *white-collar group* where the most qualified women tend to be concentrated.

We attempted to reconcile results from different econometric techniques, including FE-IV and the dynamic IV approach developed by Arellano and Bover (1995) and Blundell and Bond (1998). The appropriateness of instruments and their validity in terms of both economic and statistical theory was assessed by comparing results drawn from different specifications. The use of a variety methods to verify the relationships between the female share of jobs and some variables related to the economic development process provides a sound empirical basis for policy analysis.

Contrary to what has been reported in other studies for India (Tekani & Kucera, 2021; Gupta, 2021), the evidence presented in this paper indicates that trade liberalization in Colombia is associated with an increasing feminization of manufacturing employment. Given that the data used in this empirical application is drawn at the firm level, we could not have access to wage or labor cost data disaggregated by sex to know whether the increased feminization of manufacturing employment could be a cost cutting strategy in which more expensive male workers are replaced by cheaper but equally productive female workers. It could also be the case that because women are less prone to unionizing, employers in the manufacturing sector of Colombia are willing to hire a higher proportion of female workers as a cost-cutting strategy[10]. The nature of our data does not allow us to validate such hypotheses although they could be verified in future research, probably by incorporating information from other statistical sources such as household surveys.

10 Statistics about unionization rates by gender are scarce for Colombia and other developing countries. According to Cobble (2012), women are less likely than men to be unionized, particularly in developing countries where they represent just 40% of workers affiliated to trade unions.

Finally, it should be remarked that this investigation in its present state could be further developed in a number of ways. More recent data for manufacturing industries in urban Colombia, which is available under a new ISIC revision and an entirely new methodology from 2001 onwards, should reveal the effects of increased trade flows from the rest of the world on the gender differentiated patterns of employment, particularly in the case of increased imports of manufactured goods from China. Also, it would also be important to determine the extent to which other macroeconomic variables such as the exchange rate have affected the profitability of the manufacturing sector and whether this has had a differentiated effect in the gender composition of employment. Such effects are of particular importance after the international recession of 2008/2009 in which the prices of commodities such as oil experienced an abrupt surge that adversely affected the competitive position of Colombian manufactures due to the appreciation of the Colombian currency.

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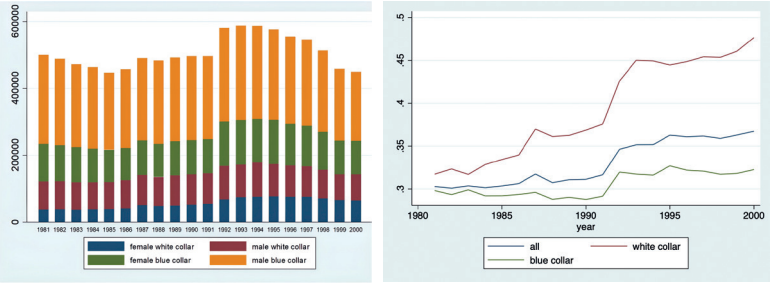
Figures

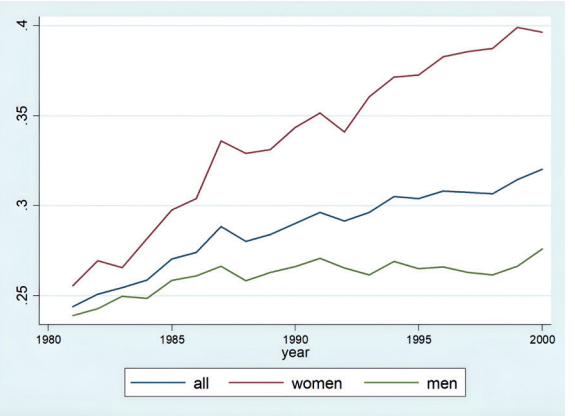
Figure 1: Number of jobs and gender composition of employment across white and blue collar workers and gender in all manufacturing industries, Colombia: 1981-2000

a) Number of jobs *b)% of female jobs*



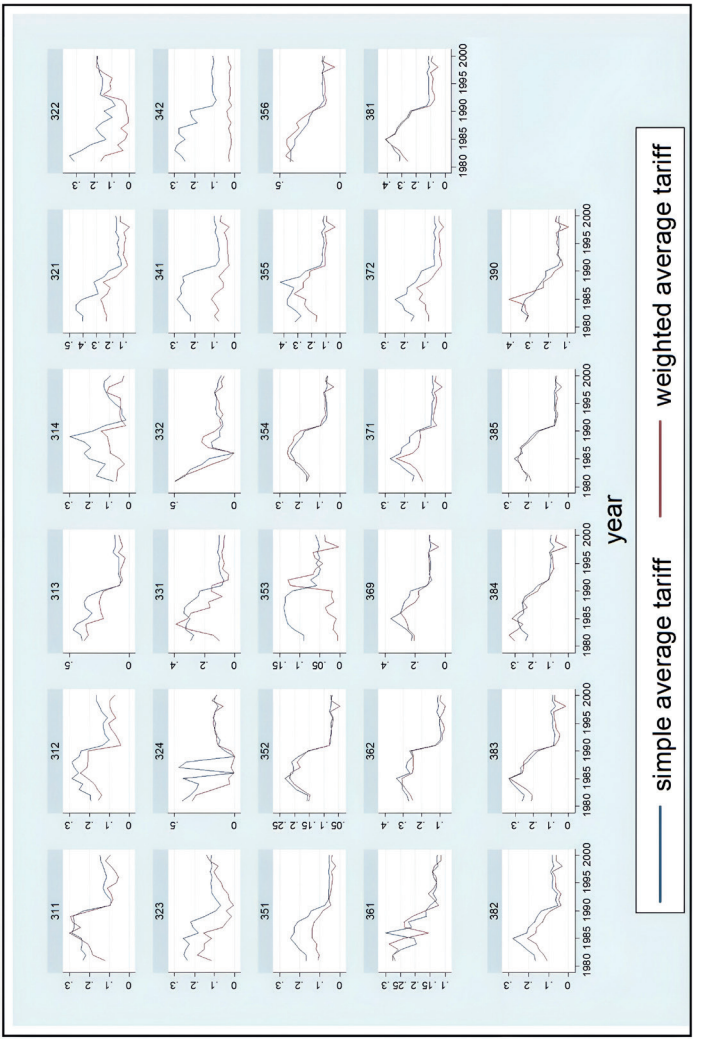
Own estimates based on Annual Manufacturing Survey microdata.

Figure 2: Proportion of white-collar jobs by gender in all manufacturing industries, Colombia: 1981-2000



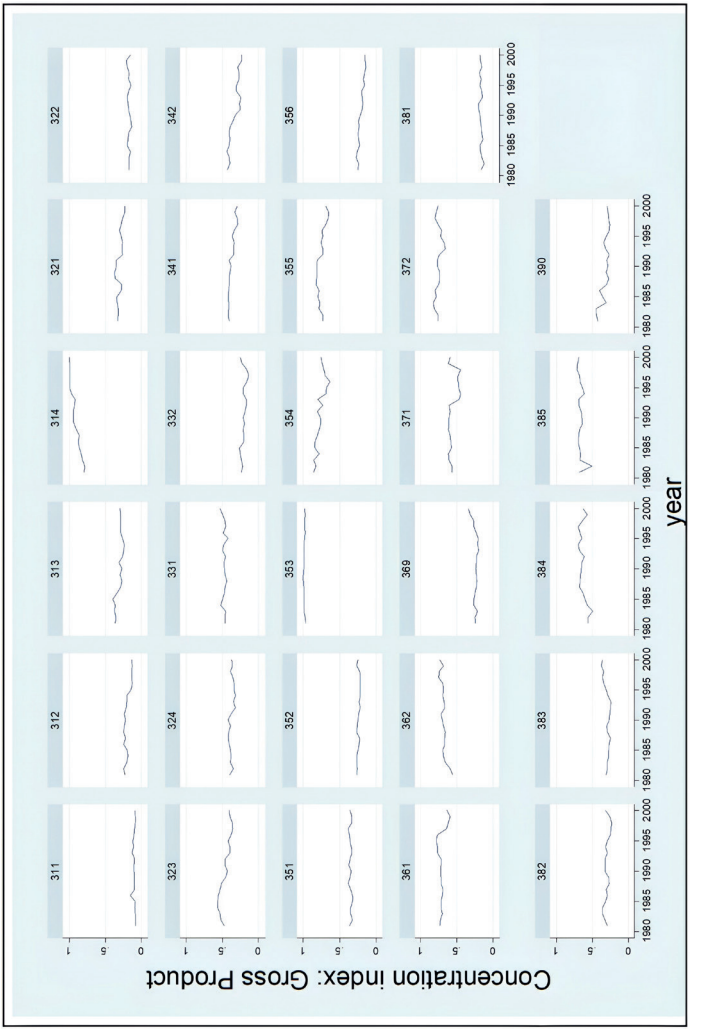
Own estimates based on Annual Manufacturing Survey microdata.

Figure 3: Simple and weighted average tariffs across manufacturing industries, Colombia: 1981-2000



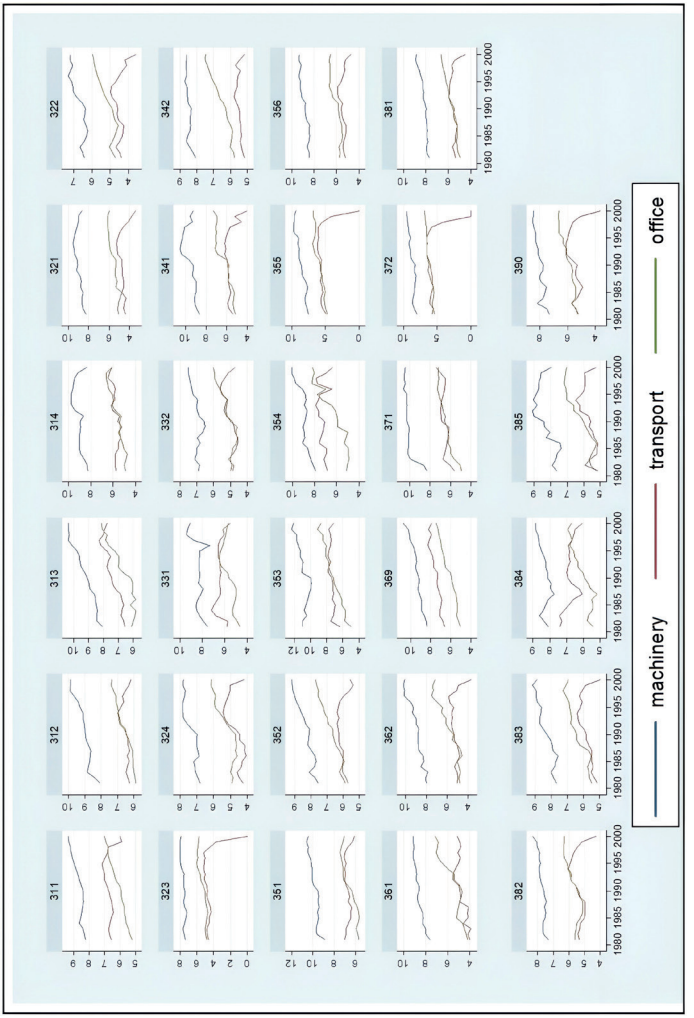
Own estimates based on tariff data from National Planning Department -DNP. Weights are based on import values in Col Pesos.

Figure 4: Concentration Indices (based on Gross Product Values) across manufacturing industries, Colombia: 1981-2000



Own estimates based on Annual Manufacturing Survey microdata.

Figure 5. Capital Equipment (Machinery, Transport and Office) per Worker across manufacturing industries, Colombia: 1981-2000



Own estimates based on Annual Manufacturing Survey microdata.

Table 1 Variable definitions

Label	Variable	Definition
femshare	female share of jobs: all workers	female share of jobs in industry *i* at time *t* amongst all workers
wc_fe-mshare	female share of jobs: white-collar workers	female share of jobs in industry *i* at time *t* amongst white collar workers
bc_fe-mshare	female share of jobs: blue-collar workers	female share of jobs in industry *i* at time *t* amongst blue collar workers
ipc	import penetration coefficient	$$ipc_{it} = \frac{M_{it}}{Y_{it} + M_{it} - X_{it}}$$ where Y, M and X denote, respectively, the gross product, imports and exports of industry *i* at time *t*.
eoc	export orientation coefficient	$$eoc_{it} = \frac{X_{it}}{Y_{it}}$$ where X and Y denote, respectively, exports and the gross product of industry *i* at time *t*.
CIGP	Concentration index	See expression (1) in text and details on it.
lnkpw_ mach	ln(capital equipment per worker: machinery)	See expression (2) in text and details on it
nkpw_ trans	ln(capital equipment per worker: transport)	See expression (2) in text and details on it
lnkpw_ office	ln(capital equipment per worker: office equipment)	See expression (2) in text and details on it

Table 2: Panel summary statistics: within and between variation

Variable		Mean	Std. Dev.	Min	Max	Observa-tions
isic	overall	349.897	25.064	311	390	N = 580
	between		25.486	311	390	n = 29
	within		0.000	349.897	349.897	T = 20
year	overall	1990.5	5.771	1981.0	2000.0	N = 580
	between		0.000	1990.5	1990.5	n = 29
	within		5.771	1981.0	2000.0	T = 20
femshare	overall	0.2701	0.1598	0.0096	0.8135	N = 580
	between		0.1596	0.0785	0.8007	n = 29
	within		0.0296	0.1824	0.3727	T = 20
wc_fe-mshare	overall	0.3761	0.1019	0.0364	0.6704	N = 580
	between		0.0861	0.1597	0.5987	n = 29
	within		0.0567	0.2528	0.6486	T = 20
bc_fe-mshare	overall	0.2295	0.1889	0.0032	0.8697	N = 580
	between		0.1899	0.0224	0.8516	n = 29
	within		0.0281	0.1200	0.3487	T = 20
CIGP	overall	0.4429	0.2462	0.0836	0.9990	N = 580
	between		0.2463	0.0985	0.9894	n = 29
	within		0.0442	0.2799	0.5702	T = 20
ipc	overall	0.2189	0.2218	0.0005	0.9456	N = 580
	between		0.2023	0.0176	0.7511	n = 29
	within		0.0980	-0.1337	0.7527	T = 20
eoc	overall	0.1717	0.2237	0.0006	1.8409	N = 580
	between		0.1636	0.0041	0.8421	n = 29
	within		0.1555	-0.4653	1.3417	T = 20
lnkpw_mach	overall	8.6275	0.9976	6.2089	12.3023	N = 580
	between		0.8888	6.7036	10.9253	n = 29
	within		0.4807	6.8639	10.0045	T = 20

lnkpw_ trans	overall	5.8333	1.0772	0.0000	8.2848	N =	580
	between		0.9121	4.4789	7.4737	n =	29
	within		0.5964	0.5224	7.0625	T =	20
lnkpw_ office	overall	6.0298	0.8434	4.2137	9.1494	N =	580
	between		0.5027	5.1884	7.1754	n =	29
	within		0.6833	3.8663	8.0038	T =	20

Table 3: Testing the relevance of instruments: fixed-effects and first-differences estimates

Variable	(1) ipc	(2) D.ipc	(3) CIGP	(4) D.CIGP	(5) eoc	(6) D.eoc
a_tariffs	-0.5688*** (0.1193)					
D.a_tariffs		-0.1196** (0.0593)				
ln_noplants			-0.1075** (0.0399)			
D.ln_no-plants				-0.1022*** (0.0240)		
rtb					0.2237** (0.0816)	
D.rtb						0.2995*** (0.0824)
Constant	0.3189*** (0.0210)	0.0073*** (0.0024)	0.9762*** (0.1978)	-0.0007*** (0.0000)	0.1933*** (0.0079)	0.0096*** (0.0005)

Observa-tions	580	551	580	551	580	551
R-squared	0.2586	0.0078	0.1702	0.0620	0.1223	0.2061
Number of isic	29	29	29	29	29	29

*Cluster-robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Notes: (1) features ipc as a dependent variable against average tariffs (a_tariffs) as a single explanatory variable while (2) features the same variables in differences. (3) features CIGP as a dependent variable against the logarithm of the number of firms (ln_noplants) as a single explanatory variable while (4) features the same variables in differences. (5) features eoc as a dependent variable with the relative trade balance (rtb) as a single explanatory variable while (6) features the same variables in differences.*

Table 4 Fixed-effects IV and dynamic IV estimates of female share equations; trade variable: import penetration coefficient (ipc)

Variable	(1) ipc	(2) D.ipc	(3) CIGP	(4) D.CIGP
Lagged Dep. Var.				0.7729*** (0.0316)
Ipc	0.0892*** (0.0128)	0.1708** (0.0701)	0.1065*** (0.0166)	0.0006 (0.0129)
ln_noplants			-0.1075** (0.0399)	
D.ln_no-plants				-0.1022*** (0.0240)
rtb				
D.rtb				
Constant	0.3189*** (0.0210)	0.0073*** (0.0024)	0.9762*** (0.1978)	-0.0007*** (0.0000)