

TESTING FOR R&D' RENTS IN SKILLED WORKERS' WAGES IN THE MANUFACTURING INDUSTRY OF COLOMBIA¹

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ABSTRACT

This paper examines if firm investments in research and experimental development (R&D) activities generate quasi-rents in the wages of skilled workers in the manufacturing industries of Colombia. It will test the hypothesis that variations in wages of skilled workers and in R&D spending are both endogenously determined in manufacturing firms. By testing this hypothesis I determine whether skills and R&D activities offer an explanation for quasi-rents among workers wages.

Keywords: Research and Development. Skilled workers. Wages. Quasi-rents.

JEL classification: J31, J44.

I. INTRODUCTION

This paper will examine if firms' investments in research and experimental development (R&D) activities generate quasi-rents in the wages of skilled workers in the manufacturing industry of Colombia. I will test the hypothesis that variations in wages of skilled workers and in R&D spending are both endogenously determined in manufacturing firms. By testing this hypothesis, I intend to determine whether skills and R&D activities offer an explanation for quasi-rents among workers wages.

The second chapter examines the literature on wage determination and technology change, as well as rent-sharing theories and other pertinent literature. The third

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This study is a memorial to my beloved uncle, Jose E. Umaña Mendoza, leading human rights lawyer of my country, murdered in Bogota April 18th of 1998. In memory of his ideal of a just world.

chapter is a first approach to the rent-sharing problem, in which, based on previous literature, three wage equations are estimated. The fourth chapter is the main contribution of the dissertation and develops a new theory. In order to test the main hypothesis of this new theory, the fifth chapter estimates a system of equations using a cross section data set (1996) on 886 establishments from Colombia's manufacturing industry. In the sixth chapter there are the conclusions, recommendations for future research and discussion of policy issues.

Quasi-rents to workers reduce firms' incentives to invest in R&D activities. They are one way in which workers appropriate R&D returns. Colombia's manufacturing industry has a small proportion (1/4) of firms investing in R&D. It would increase competitiveness and economic growth if manufacturing industry firms increased R&D spendings. This is the reason why it is important to study the extent to which quasi-rents determine skilled workers' wages. In this way, this study will provide elements for the formulation of policies to enhance R&D activities at Colombia's manufacturing industry. At present, the enhancement of both skills among the labor force and R&D activities are considered to be the solution for economic growth and competitiveness problems in less developed countries (LDCs). But if educational-level enhancements generate only quasi-rents to workers, economic and educational policy-makers should be alerted that the medicine could turn to be worse than the disease.

II. LITERATURE REVIEW ON WAGE DETERMINATION AND TECHNOLOGICAL CHANGE

Past analysis of the effects of technological change on wages has largely assumed that workers are equally skilled². These studies build on the assumption that inventions affected all workers identically regardless of their innate ability and skill level. More recent literature correctly distinguishes between skilled and unskilled workers in the determination of the impact of technological change on wages. One argument is that successful introduction of new physical capital or a new technology requires significant learning on the part of employees. As considered in Bartel and Lichtenberg (1991), learning is a function of both effort and ability, and the latter is an increasing function of *workers education*. Other kinds of arguments [see Choi (1993)] stress that higher education levels improve *learning efficiency*. Further, other studies [Aghion and Howitt (1998)] argue that education increases not only learning efficiency, but also individuals' capacity to innovate and to adapt new technologies (i.e. education increases innovative and adapting efficiencies)³.

Human capital theory points out that wage differentials emerge during periods of market adjustment for educated workers. Such theory explains that wage differen-

² As in Neary 1981, Sinclair (1981), Katsoulacos (1986), Karni and Zilch (1988) [cited in Betts (1993)].

³ Redding's (1996) model studies education and innovative activities as complementaries.

tials emerge as the supply or demand for educated workers adjustments towards equilibrium (Mincer 1991). Supply side adjustments are mainly due to changes in rates of return to education⁴. Demand side adjustments occur mainly because of increases in demand for human capital services or products (e.g. due to the purchase of new physical capital) or because the productivity of educated labor grows as a result of technological change. In order that both physical capital and/or technology changes result in an increasing demand for educated workers, they must be less substitutable or more complementary for skilled than for less skilled labor [*skill bias of physical capital or technology accumulation (SBPT)*]⁵.

Milgrom and Roberts (1992) define rents and quasi-rents as follows: “A rent is the portion of earnings in excess of the minimum amount needed to attract a worker to accept a particular job (...) A quasi-rent is the portion of earnings in excess of the minimum amount needed to prevent a worker from quitting his or her job” (pp. 269-70). We must bear in mind these two concepts because they will be used in further analysis.

The *quiddity* of this paper is an attempt to answer the following question: do differentials in skilled workers’ wages emerge in the form of (*quasi-*)rents for R&D in the presence of SBPT?

Innovative activities are, in general, designed to produce or generate knowledge. The problem of knowledge appropriability may not be as severe as former theory has taught us, even if the effectiveness of the patent system is limited as an incentive to innovation [Stoneman (1983)]. Geroski (1995) argues that problems of appropriability are as much consequence of low costs of transmission as not and anything that raises these costs reduces the importance of problems associated with appropriability. I would add that appropriability is more likely if imitation costs are small and anything that raises this costs [e.g. learning economies, natural reaction lags, barriers to entry [Arrow (1962)], reduces the importance of problems associated with appropriability.

If we assume that, within firms, costs of transmission or imitation are much lower than between firms, low costs allow for greater *knowledge leaks* among workers within the firm than between firms. These leaks that feed through into some workers within firms are enough incentive for them to withhold information in order to increase their influence in the firm [Milgrom and Roberts (1987)]. Actually, they may be in a position to demand a greater wage or else to refuse to provide information (e.g. how to operate a new technological acquisition for the production process) to

⁴ The return to the investment cost of education is the gain in earnings associated with an additional year of education. This return is the education (relative) wage differential or the educational premium.

⁵ Betts (1993) advises that any empirical analysis of the impact of technical change in earnings or employment by industry is likely to be seriously biased, unless it allows for the possibility of technical change which is not neutral with respect to skills. So, empirical analyses of the impact of technical change in earnings or employment by industry must not rule out the possibility of technical change that is not neutral with respect to skills.

new or other workers. So, leakages of knowledge would leave certain workers in the firm with a greater bargaining power for wage settlements or negotiations. Further, knowledge leaks only put skilled workers in a better position to bargain (i.e. skills and learning are essential determinants in the appropriation of knowledge)⁶.

Thus, we can suggest a strong association between innovation and the bargaining power of skilled labor. When SBPT is present, skilled workers' learning and innovative abilities are their most reliable instruments for enhancing their bargaining power. Traditionally economic theory links bargaining power with unions power. I am not aware of studies linking innovative activities to skilled workers' bargaining power. However, bargaining relationships are not limited to negotiations between unions and employers but, actually, have several more prominent characteristics according to social psychology theories [Rubin and Brown (1975, p. 18)]:

1. At least two parties are involved.
2. The parties have a conflict of interest with respect to one or more different issues.
3. Regardless of the existence of prior experience or acquaintance with one another, the parties are at least temporarily joined together in a special kind of voluntary relationship.
4. Activity in the relationship concerns: (a) the division or exchange of one or more specific resources and/or (b) the resolution of one or more intangible issues among the parties or among those whom they represent.
5. The activity usually involves the presentation of demands or proposal by one party, evaluation of these by the others, followed by concessions and counterproposals. The activity is thus sequential rather than simultaneous.

Everyday life is full of such kind of settings in which individuals decide whether to attempt to influence others (e.g. within neighbourhoods, family, etc.). So, bargaining could be understood as *an attempt to influence others* and not simply union-employer negotiations. Furthermore, union bargaining in Colombia is more related to political struggles between the host country and multinational corporations⁷, particularly within enterprises exploiting natural resources (e.g. petroleum) and public telecommunications enterprises (as a result of privatisation). Unions in developed countries have greater coverage than in less developed countries and their behaviour is less related to historic and political struggles.

So, in the absence of strong and powerful workers unions' who has bargaining power in LDCs like Colombia? Knowledge leaks leave skilled workers in a better

⁶ Actually, according to Hirshleifer (1971) (cited in Geroski (1995)), innovators or innovating firms are able through speculation or resale of the innovation to capture a portion of the pecuniary benefits of their innovation.

⁷ For a study of this kind of bargaining problems in the manufacturing sector in developing countries see Kobrin (1987).

bargaining position in the presence of *SBPT*, as discussed above. Knowledge leaks within firms that innovate should be greater than in firms that do not innovate. Innovative firms with R&D projects would rely on skilled workers' abilities to learn and innovate (non-innovative firms would rely less in skilled workers). Skilled workers would then have greater bargaining power within innovative firms than in non-innovative firms. Social psychology theory stresses that bargaining power depends mostly on how parties *use information on each other's dependence* to estimate the utility of an influence attempt (Lawler and Bacharach (1979)). If skilled workers are aware of this reliance they could take advantage and obtain an influential position in the firm. But even if skilled workers did not realize their importance for, say, R&D projects, knowledge leaks that feed through to skilled workers may *minimize their influence costs* in pay negotiations, leaving them better-positioned for negotiations or bargaining. So, skilled workers' influence costs would be minimized as a consequence of innovation within firms. Learning and innovative skills would then increase bargaining efficiency in favor of higher pay. In a few words, skills obtained, say, as a by-product of costly innovative activities within the firm, or by training or education, confer skilled workers with greater bargaining power.

These arguments suggest that the trilogy skilled labor force-technological change-wage determination could best be modeled in a non-competitive theory as reflected in insider forces in an imperfectly competitive labor market. A past study for Colombia (Tan and Batra (1997)) happens to support a competitive theory approach. Using firm-level data from Colombia, Mexico, and Taiwan (China), the article compares the effects of research and development, worker training, and exports on the wages of skilled and unskilled workers. The results suggest that technology investment lead to large wage premiums for skilled workers but not for unskilled workers. These wage premiums are primarily the result of investments in research and development and in training, while exporting is relatively less important except in Colombia. Nevertheless, Tan and Batra discard *prima facie* Groshen's (1991) hypotheses that unexplained differentials may reflect quasi-rents from imperfectly competitive markets. Tan and Batra claim that there is little evidence of this hypothesis (p. 60). However, I believe they ruled out the quasi-rents hypothesis because they are not aware of the great amount of empirical studies carried out that support the hypothesis that unexplained differentials may reflect quasi-rents from imperfectly competitive markets in developed countries.

A. Rent-Sharing Theory: Advances and Results

If we view wage determination as a rent-sharing in which workers and firms either bargain over pay or *act as if they do* (Pencavel (1991), Oswald (1996)), *skilled* workers would have major bargaining power due to *SBPT*. The 'rent-sharing' model-type constitutes a non-competitive theory in which rents are divided between firms and employers. It is based on Slichter's seminal paper (1950), which work helped to create a new area of research by uncovering the strong rank correlation between pay and employer's prosperity (Carruth and Oswald (1989)). Slichter examined why ho-

mogenous labor earned different wages across industries and found that in US manufacturing wages appeared to be correlated with employer's ability to pay. Supporting Slichter's results, Katz and Summers (1989) found that in American Industries there appeared to be wage differentials that could not be wholly attributed to skill differentials or working conditions⁸.

Teal (1996) provides strong support of the rent sharing theory of wage determination in a developing country. It is shown that factors such as unions, ownership, size, profitability, and firm age, all operate to raise earnings substantially⁹. These results are very similar to recent evidence for developing countries labor markets (Blanchflower, Oswald and Sanfey (1996)¹⁰). Blanchflower *et al* (*ibid.*) and Cristopheldes and Oswald (1992), Currie and McConnell (1992), Blanchflower, Oswald and Garret (1990), Nickell and Wadhvani (1990), Denny and Machin (1991) and Hildreth and Oswald (1994) all have strong similarities in their findings. Even more, when profitability is instrumented (by output movements in the sector to which an industry sells) almost all the variation in wages is due to rent-sharing. In general, results change enormously when the profit variable is instrumented.

More specific evidence of rent-sharing in the innovative process appears in Dickens and Katz (1987). They analysed the relationship between wage rates and the industry's ratio of R&D expenditures to sales. They found that wages were positively related to R&D-intensity in the non-union sector. In the unionised sector, however, most specifications suggested that the correlation between wages and R&D-intensity is negative¹¹. Van Reenen's (1996) paper instruments profits in rent-sharing models and supports the existence of quasi-rents from innovation. He used the 'rent-sharing' approach to examine if rents from innovation were shared among firms and employees. Van Reenen found that in a panel data set of 600 Britain firms innovations might be a good instrument for proxies for rents such as profitability, quasi-rents or Tobin's (average) Q ¹².

The conclusion from these studies is that "when an employer enjoys a sustained exogenous burst of profits, it feeds through into higher long-run pay for its employees, not only in unionized but in non-unionized settings" (Oswald, 1996). But why would workers appropriate innovation or R&D returns and -on the way- undermine the incentives to undertake such kinds of activities? Van Reenen suggests three interpretations for innovation rents be 'up for grabs' for workers: 1. The long lag times

⁸ It seems that rent-sharing models are based on the belief that union models might be more general than previously thought (Pencavel (1991)).

⁹ When the profit term is instrumented the size of the coefficient is greatly increased implying that a move from the 10th to 90th percentile of the distribution of firm profits would increase earnings by 58%!

¹⁰ The profitability variable at a wage equation enters positively and with a standard error less than half its coefficient.

¹¹ When they threw out a disproportionate share of unionized employees, they found that the effect of the profitability measure in wages was doubled from that of the full sample.

¹² Instrumental variable estimates of the elasticity between wages and quasi-rents were about 0.29.

between research and results compared with tangible capital 2. The shorter time horizon of workers than shareholders (perhaps because of the finite duration of labor contracts) 3. The large elements of sheer luck in innovative success. As we can see, bargaining power is not considered. The strong bargaining power of skilled workers in the presence of SBPT is still missing from rent-sharing theory.

B. Other pertinent literature

Betcherman's (1991) paper on technological change and bargaining power finds that the relationship between technological change and the union wage premium differed for skilled and unskilled labor. He used data from a survey of Canadian establishments to consider the effects of computer-based process technological change on wage bargaining power. The analysis finds that union wage differentials for blue-collar workers as a whole were lower among firms that had introduced process computerization than among those that had not. The union wage effect was lower for skilled workers and higher for general manual occupations in the sub-sample where process computerization had occurred.

This kind of wage effect bias towards unskilled workers could be explained by fairness arguments. For example, Akerlof and Yellen (1990) study a case, General Motors, in which the company finally could not implement a premium to executive managers. If firms have to pay high wages to some group of workers—for certain reasons- demands for equity pay will raise the general wage scale for other labor in the firm, who would otherwise see their pay as unfair. Unions would then be standing up in favor of those who benefit less from technological change (i.e. unskilled workers). This could be supported by the fact that unions have commonly presented resistance to change¹³.

Dertouzos and Quinn (1985) document the results of research on how the bargaining relationship between workers and firm managers affects the introduction of new technologies. Using data from the newspaper industry, the research documents the extent of technology diffusion and labor displacement, and explains why firms and workers under varying circumstances rely on different bargaining responses to the incorporation of new technologies into production processes. The following are among the main empirical results: (1) Worker layoffs are rare; (2) non-unionized firms are no less likely to compensate workers than union firms; (3) the most frequently observed bargaining response is natural attrition; (4) non-unionized firms exhibit greater reliance on programs to retrain workers for other jobs in the firm; and (5) group-owned newspapers did not adopt the new technology more quickly.

¹³ Since the early industrialization, technical change has been linked with some mechanized techniques of production that appeared to be a real threat to set out labor. For instance, David Ricardo's chapter 'On Machinery' stated that 'machinery an labour are in constant competition', referring rather to mechanization than to technological change (Petit (1995), p. 369).

Other literature deals with the problem of wage differentials from another perspective. According to efficiency-wage theory, increases in wage differentials arise because unemployment is greater in some industries than in others. The latter disciplines workers [Shapiro and Stiglitz (1984)], increases motivation, and reduces recruiting costs. In a few words, efficiency 'wage-curves' illustrates that high unemployment makes the employees keen to keep their jobs because it is difficult to find another. These employees are reluctant to shirk for fear of being detected and fired. Knowing this, firms pay low wages in order to extract the required effort from their workers [Blanchflower and Oswald (1994)]. Recent explanations of unemployment [Nickell (1997)] argue that labor market rigidities such as legal protection of employees increase the cost of hiring and of the adjustment of employment. So, laws, in the short run, reduce employment because they reduce the flow of workers into the pool of unemployment, but, in the long run, the flow increases.

Fair-wage theory claims to offer an explanation for industry wage differentials, offering a theory of effort between actual and fair wages. It explains that fairness is the reason why the premiums paid to different occupations are positively correlated within an industry. However, Akerlof and Yellen (1990) argue that efficiency wages¹⁴ offer no natural explanation for the fact that unemployment is greater for unskilled works than for skilled works. Skilled workers are more difficult to monitor than unskilled workers. Worker discipline models would thus predict higher unemployment for skilled labor than for unskilled labor, unless shirking yields significantly greater utility to unskilled than to skilled workers.

Although this criticism of fair-wage-theory seems quite "fair", it still relies on the strong assumption that the disutility of shirking for unskilled workers is significantly greater for skilled workers than for unskilled worker, so that the prediction of efficiency wage theory fails in explaining the reason for the greater unemployment of unskilled workers. Furthermore, according to Clark and Oswald (1994), the disutility of being caught shirking and fired (i.e. becoming unemployed) is relatively more distressing for highly educated individuals (a kind of comparison effect caused by high aspirations and standards) than in the less educated. So, shirking may yield less disutility (i.e. greater utility) for unskilled than for skilled workers because the disutility of being caught, fired and subsequently unemployed for skilled is greater. So, based on these arguments, wage differences would be a means to increase the effort of high ability workers. According to this argument, the critique of efficiency wages would not be entirely "fair", because this theory could lead to a quite accurate explanation for greater unskilled unemployment. Although the validation of this critic goes beyond the scope of this dissertation, it leaves us with an important idea that is now common in wage differential theories: that is *the distinction among skilled and unskilled workers matters in the explanation of wage differentials*.

¹⁴ This theory argues that wage differentials could be reflecting wage premiums as a mean to compensate a greater effort on the part of high ability workers, according to efficiency wage theory. Wage premiums intend to increase the expected penalty of being detected shirking and hence reducing the extent of shirking.

Fairness theories may be useful to explain why equity may help to reduce skilled workers' power within firms. If workers are involved within the firm in participatory management, quality circles (groups of employees who make suggestions to improve productivity and product quality and other similar management techniques), decision making, etc., influence attempts, rent-seeking and politicking may be less prominent in skilled workers agendas. In fact, "Japanese personnel policies seem especially conducive to constructive participation by workers, and firms in USA with Employee Stock Ownership Plans find it more attractive to include a wide group of workers in company decision making" (Milgrom and Roberts, 1992, p.282).

C. Summary and concluding remarks

Recent literature on the effects of technological change on wages distinguishes between skilled and unskilled workers, because they consider that the successful introduction of a new physical capital or technology requires significant learning on the part of skilled employees. Learning and innovative efficiencies improve with the education of the workers and wage differentials emerge during periods of market adjustment for educated workers. Physical capital and/or technology change could, hence, result in an increasing demand for educated workers, but only if these changes are less substitutable (or more complementary) for skilled than for less skilled labor (skill bias of physical capital or technology accumulation (SBPT)).

Problems of appropriability of knowledge are consequence of low costs of transmission and of imitation. Anything that decreases these costs increases the importance of problems associated with appropriability. Education lowers these costs (i.e. enhances learning and innovative efficiencies), so it allows greater knowledge *leaks* among skilled workers within the firm or organization. Knowledge leaks from innovative activities feed through into skilled workers, which is enough incentive for them to withhold information in order to increase their influence in the firm. They would then be in a position to demand a greater wage or else to refuse to provide information to new or other workers. So, leaks of knowledge due to innovative activities would leave skilled workers with greater bargaining power in wage settlements or negotiations.

When knowledge leaks feed through to skilled workers the influence costs in attempts to gain pay raises would then be lower, leaving them better-positioned for negotiations or bargainings (e.g. pay raises). So, influence costs would be minimized as a consequence of innovation within firms. Skills would then increase bargaining efficiency in favor of skilled workers pay. If wage determination is conceived as a rent-sharing in which workers and firms either bargain over pay or act as if they do, the skilled workers would be better off in firm's rent-sharing.

In Colombia, unions have low coverage and a history of political struggle. So, investments in human capital could be understood as a decentralized way of response in order to obtain a bargaining power, as an alternative to unionization. So the trilogy human capital-technological change-wage determination could be best

modelled using non-competitive theory, reflecting insider forces such as quasi-rents in an imperfectly competitive labor market.

Rent-sharing theory has evolved as an imperfectly competitive labor theory. It is an elaborate theory that has many robust and interesting results. Although Slichter's seminal article started this line of research almost 50 years ago, it is a new theory that has not yet been given global recognition. It will be very interesting to see how this theory will disseminate in the empirical analysis of less developed countries. Certainly, new insights into LDCs will come from future research using this paradigm.

However, rent-sharing empirical studies rely on traditional concepts in economic theory such as bargaining-through-unionization on alternate measures of bargaining are not contemplated. Neighbour sciences such as social psychology provide interesting and imaginative alternatives that could lead economists to broaden the concept of bargaining. It is an everyday event that encompasses settings in which individuals decide whether to attempt to influence others (e.g. within neighbourhoods, family, etc.). Rent-sharing theory will need to look at bargaining as a more general problem of influence attempts rather than as simply union-employer negotiations. On the other hand, fairness theories may be useful to explain why equity may help to reduce skilled workers' influence attempts within firms. This theory has the important idea that involving workers and firms interests, reduces resources devoted to influence others within the firm and, in this way, workers and firms interest would merge.

III. TESTING RENT-SHARING HYPOTHESIS

Following Oswald (1996) and Blanchflower *et al* (1996), rent-sharing model starts with a Nash bargain in wages:

$$\max_{w, n} \phi \log [(u(w) - u(\varpi)) n] + (1 - \phi) \log \pi \quad (1)$$

Where ϕ is the bargaining power of employees, $u(w)$ is the worker's utility from wage w , v is the wage available from temporary work in the event of a breakdown in bargaining, n is employment, and π is profits. This formulation relies on the assumption that in the event of bargaining delay the firm earns zero profit and the worker wage v , and by the choice of units the variable n is also the probability of employment. Define profits as $mf(n, k, r) - wn - p_k k - p_r r$, where m is product price, f is a concave production function, w is wage, n is level of employment, k is capital, p_k is its price, r is research capital and p_r is its price. At an interior optimum, the following first order conditions hold:

$$n: \frac{\phi}{n} + \frac{(1-\phi)[\mu f'(n) - w]}{\pi} = 0 \quad (2)$$

$$w: \frac{\phi u'(w)}{[u(w) - u(\bar{w})]n} - \frac{1-\phi}{\pi} = 0 \quad (3)$$

Rewriting equation 2 as

$$\frac{u(w) - u(\bar{w})}{u'(w)} = \left(\frac{\phi}{1-\phi} \right) \frac{\pi}{n} \quad (4)$$

and using the approximation:

$$u(\bar{w}) \cong u(w) + (\bar{w} - w)u'(w) \quad (5)$$

produces:

$$w \cong \bar{w} + \left(\frac{\phi}{1-\phi} \right) \frac{\pi}{n} \quad (6)$$

Equation 6 shows that the equilibrium wage is determined by the outside wage available in the event of a temporary dispute in bargaining, the relative bargaining strength of the two sides, and the level of profit-per-employee¹⁵. Most rent-sharing literature uses this kind of model to suggest an empirical approach to explaining workers' or plants wages. More recently this literature has dealt directly with the fact that profits are endogenous.

For example, Van Reenen's (1996) paper instruments profits in a rent-sharing model. The paper supports the existence of quasi-rents from innovation, proving the creation of rents in the innovative process. Van Reenen found that innovations might be a good instrument for economic rents (such as profitability, quasi-rents or Tobin's (average) \mathcal{Q}). The wage equation that he tested was the following (panel of British firms (1945-83)):

$$\text{Wages} = W(\underline{W}, s, I, \text{R\&D}, O) \quad W_{\underline{W}} > 0, W_s > 0, W_{\text{R\&D}} > 0, W_I > 0 \quad (7)$$

Where \underline{W} = alternative wage, s = relative union power and I = index of relative innovations, R\&D = research and development spendings intensity O = other variables.

¹⁵ $v = c(w_0, b, U)$ where w_0 : going wage in to her sectors of the economy; b : is the level of income when unemployed; U : unemployment rate among workers of the type employed by the firm.

We take a similar approach here using a cross-sectional database on Colombia's manufacturing industry. This will allow us to have a first approximation to the innovation rent content of skilled workers' wages, based on the rent-sharing model described above. There will be no modifications to the structure of equation, but some exogenous variables will be changed. The estimation will examine the determination of skilled workers wages (discriminated by technicians, professionals and postgraduates). Skilled labor will therefore be encompassed in more homogenous labour groups. But instead of an single equation system there is a system of three endogenous variables (independent of each other):

$$W_i = W(\underline{W}, \phi, A, R\&D) \quad W_{\underline{W}} > 0, W_{\phi} > 0, W_{R\&D} > 0 \quad W_A > 0 \quad (7)'$$

Where W = wages, i = technicians, professionals, and postgraduates, \underline{W} = alternative wage (i.e. operator's wages), ϕ = measure of bargaining power and A = technological factor, $R\&D$ = research and experimental development spending.

A. Measurement of variables

The database is a cross-sectional one (it contains information of 886 establishments in the manufacturing industry of Colombia in 1996). Wages of skilled workers are divided in three levels: technicians, professionals and postgraduates (endogenous variables). The exogenous variables are: \underline{W} (= alternative wage), measured by operaries wages; ϕ (= bargaining power), measured by the degree of innovativeness of the firm ($0 \leq \phi \leq 1$), which is obtained calculating the average of the innovation dummy variables¹⁶; A (= technological factor), measured by the index of designs, technology embodied in capital, technology non-embodied in capital, and innovation of organization¹⁷; and $R\&D$ (= research and development activities) measured by $R\&D$ spendings¹⁸.

B. Estimation and results

As we can see from table 1, the estimation of equation 7' (by OLS) yields that *increases in R&D spendings, ceteris paribus, generates positive and highly significant increases in*

¹⁶ The establishments' questionnaire had a section where it was asked them to respond 'yes' if they made one of the following innovations and 'no' otherwise: product innovation (five types: technological enhancement, a new product as result of an innovative activity, new product associated with a new process, new product associated to the introduction of a new input and prod. differentiation) and process innovation (new process associated with a new product, new process associated with R&D, technological enhancement of process and machinery and equipment acquisition). The average of these dichotomic variables is the measurement of the bargaining power of skilled workers. See discussion of second chapter about why the degree of innovativeness is a measure of bargaining power, in particular, of skilled workers' bargaining power.

¹⁷ The aggregation of the amount of resources devoted to such variables measure this index.

technicians' and professionals' wages. Increases in the available wage in case of a bargaining breakdown (operator's wages i.e. unskilled workers) also has a positive and significant (at the 5% level) impact over all skilled workers' wages (technicians, professionals, and postgraduates) (both the technological factor and the bargaining power of skilled workers have low significance in all cases). A 1% increase in operators' wages increase 52, 35, and 81%, respectively, technicians', professionals' and postgraduates' wages (*ceteris paribus*). Postgraduates wage estimation only leaves the available wage in case of a bargaining breakdown with a positive and significant (at the 10% level) coefficient, but since the degrees of freedom are very low, the results in this estimation are not particularly conclusive.

TABLE 1

Endogenous variable β	Technicians wages	Professionals' wages	Postgraduates' wages
Exogenous variables:			
Operators' wages	0.527 (0.106)	0.352 (0.141)	0.810 (0.349)
Technology factor	-0.002 (0.025)	-0.009 (0.033)	0.021 (0.098)
R&D spendings	0.051 (0.028)	0.072 (0.038)	-0.0003 (0.085)
Bargaining power of skilled workers	-0.101 (0.148)	-0.264 (0.202)	0.498 (0.384)
Degrees of freedom	33	32	12
R ² Adjusted	0.60	0.35	0.28
<i>Source:</i> Author's calculations (Standard errors in parenthesis)			

R&D spending enhancements apparently have a positive and significant (at the 10% level) impact on skilled workers wages, such that, a 1% increase in R&D spendings would lead to a 5.1% increase in technicians' wages and a 7.2% increase in professionals' wages. In principle, these two values would measure the R&D rent skilled-wage content, supporting rent-sharing theory predictions.

C. Concluding remarks

Rent-sharing models find that endogenizing profits in the model generate enormous rent-sharing effects. When profits are instrumented with variables such as prices of exports, output movements, innovations, etc., results change enormously (from

¹⁸ Variables such as concentration, industry unemployment, among others, are not available in the database.

ten-fold to 50 fold), supporting the view that almost all the variation in wages is due to rent-sharing (i.e. there is no central role for human capital) (Oswald (1996)). A first approach to this theory for Colombia's manufacturing sector was carried out in this chapter. The estimation supports rent-sharing theory predictions that an increase in R&D spendings raises skilled workers' pay off (i.e. skilled workers wages contain an element of R&D rents).

In spite of the striking results of rent-sharing theory, instrumentation of profits only takes the theory out of the problem of endogenous variables, but it is still confines profit endogenization to an econometric problem when it may require a more ambitious theoretical approach. We have to consider for example, how is R&D spending determined within the firm? do skilled workers have a role in R&D spending determination? does the bargaining power of skilled workers affect R&D spending?

Rent-sharing theory does not supply answers to the majority of these questions. The next chapter intends to provide a theoretical framework in order to deal with such issues.

IV. NEW THEORY

I intend to analyse the association between R&D activities and the wages of skilled workers. This will allow us to evaluate if skills (i.e. learning, innovating, and adapting ability) generate appropriation of R&D rents.

A. Model

Lets assume that a firm wants to hire workers in order to carry out an R&D project within the firm (nature has previously determined the amounts of skilled and unskilled workers within the labor force). We will also assume that the selection process is done among 'insiders'¹⁹ in order to avoid problems of precontractual asymmetries of information like signalling or screening with outsiders. It is convenient to think of this problem in two stages. At the first stage the firm and the workers bargain over the wage. The bargaining power of skilled workers is not determined (as usual) by union power but is determined by the degree of innovation that the firm has undertaken (i.e. is a by-product of knowledge leaks that feed through to the skilled workers during innovative activities e.g. acquisition of technology incorporated in capital). Actually, as the firm is dealing with insiders the measure of the bargaining power (ϕ) will be given by the average proportion of innovations and technological activities undertaken within the firm, as determined by nature ($0 \leq \phi \leq 1$)²⁰. The wages of the skilled workers are bargained over a set $W = [\underline{w}, \bar{w}]$. In the event

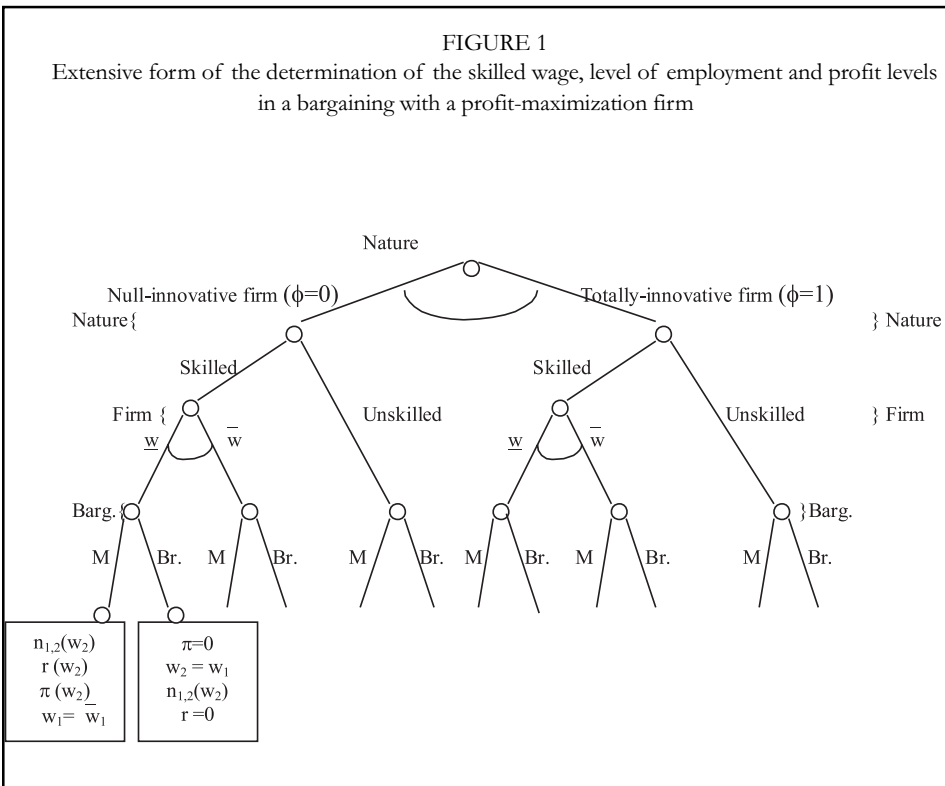
¹⁹ In reality there are two groups of potential workers: 1) The insiders: workers who have some connection with the firm at the time of the bargaining and 2) The outsiders: workers who have no initial connection with the firm (Romer (1996), pp. 465-6)

²⁰ See in chapter 3 under the title "Measurement of variables".

of a breakdown in bargaining the wage for unskilled workers (w_1) would be the wage available for skilled workers. We assume that in the event of bargaining delay the firm earns zero profit. The wage of unskilled is not subject to bargaining and it is assumed given by the labor market²¹. At the second stage, according to the common profit maximization approach, the firm chooses the levels of employment of skilled and unskilled workers to hire and the amount of resources devoted to R&D (Figure 1).

The procedure for solving this two-stage game is first to determine in the second stage of the model the level of skilled employment and R&D spendings based on the profit-maximization problem (with the wage of the skilled workers given stage 1 game). We will be able to obtain in this stage the wage bill of skilled workers ($w_2, n_2(w_2)$) and profit $\pi(w_2)$ both as a function of the skilled wage (w_2). Once we have determined the second stage of the model, we go to the first stage, where we replace the wage bill of skilled workers and profit variables (obtained in the first step) in the Nash bargaining problem for skilled wages. So, first, I will solve the second stage in order to obtain the necessary elements to undertake the first stage.

Lets imagine an extensive form of the model (Figure 1):



²¹ The product price, μ , wage of unskilled workers, w_1 , and the price of research capital, p_r , are given; w_2 , the wage of the skilled workers, is given by stage one.

Where w is the wage, n is the level of employment, 1=unskilled, 2=skilled, M , bargaining is maintained, $Br.$ means bargaining breakdown, $p(w_2)$ is profit as a function of the wage of the skilled workers, $n_{1,2}(w_2)$ are the levels of employment of unskilled and skilled workers also as a function of the wage of the skilled workers as are $r(w_2)$, research and development (R&D) spendings (w_1 is given by labor market). In the first stage the skilled workers bargain their wages according to a Nash problem of wages. In the second stage, profit-maximizing firms determine the levels of skilled employment and R&D spending. The wage and employment levels of unskilled workers are taken as given by the labor market.

B. First step: solving the second stage

The Schumpeterian model in Aghion and Howitt (1998) of education and skill-biased technical progress (chapter 10.2.3) includes a production function $y = n_1 + Ax^a$ where x is the intermediate good, $0 < a < 1$ and A is the stock of knowledge of the firm. The product of the research sector is the intermediate good x ²². I will assume that research does not depend of other sectors, but is done within the sector and depends on the levels of skilled employment (n_2) and R&D spendings (r).

The production function will then be:

$$y = n_1^\beta + A(r \cdot n_2)^\alpha \quad (8)$$

Where y is production, n_1 is the unskilled workers level of employment, n_2 is the skilled workers level of employment, A is stock of knowledge of the firm, r is R&D spending and $0 < b < 1$, $0 < a < 1$.

The profit maximization problem is the following problem:

$$\max_{n_1, n_2, r} \pi = \mu [n_1^\beta + A(n_2 r)^\alpha] - w_2 n_2 - p_r r - w_1 n_1 \quad (9)$$

Where m , the product price, w_1 , wage of unskilled workers and, p_r , the price of research capital, are given (w_2 , the wage of the skilled workers is given by the outcome of first stage).

The solution to the problem is the following for the optimal levels of skilled and unskilled level of employment, R&D spendings, and profit functions:

(optimal skilled workers' levels of employment)

²² The basic Schumpeterian model in Aghion and Howitt (1998) abstracts from capital accumulation completely.

$$n_2^* = w_2^{\frac{\alpha-1}{2\alpha(\alpha-1)+1}} \cdot (\mu A \alpha)^{\frac{1}{2\alpha(\alpha-1)+1}} \cdot p_r^{\frac{-\alpha}{2\alpha(\alpha-1)+1}} \quad (10)$$

(optimal unskilled workers' levels of employment)

$$n_1^* = \left(\frac{w_1}{\mu\beta} \right)^{\frac{1}{\beta-1}} \quad (11)$$

(optimal R&D spendings)

$$(p_r \cdot r)^* = w_2^{\frac{-\alpha}{2\alpha(\alpha-1)+1}} \cdot (\mu A \alpha)^{\frac{2\alpha-1}{(2\alpha(\alpha-1)+1)}} \cdot p_r^{\frac{2\alpha^3+3\alpha^2-3\alpha+2}{2\alpha^3-\alpha+1}} \quad (12)$$

(Substituing equations 5, 7 and 8 in equation 2):

(optimal level of profits)

$$\pi^* = -w_2^{\frac{\alpha(2\alpha-1)}{2\alpha(\alpha-1)+1}} \cdot B + \left(\frac{w_1}{\mu\beta} \right)^{\frac{1}{\beta-1}} (\mu - w_1) \quad (13)$$

Where

$$B = \left(\frac{\mu A \alpha}{p_r^\alpha} \right)^{\frac{1}{2\alpha(\alpha-1)+1}}$$

C. Second step: solving the first stage

The Nash problem of wages is as follows:

$$\max_{w_2} \phi [w_2 \cdot n_2(w_2) - w_1 \cdot N(w_2)] + (1-\phi) [\pi(w_2)] \quad (14)$$

Where ϕ is the bargaining power of employees ($0 < \phi < 1$) (i.e. the skilled workers) and N is the sum of employed and unemployed skilled labor. It is premultiplied by the wage for unskilled workers (w_1) because this would be the wage available for skilled workers in the event of a breakdown in bargaining. This formulation relies on the assumption that in the event of bargaining delay the firm earns zero profit. (The rest of variables have the same denomination as in the second stage.)

Substituting equations 10 and 13 in equation 14, the Nash maximization problem yields the following result:

$$w_2 = \frac{w_1 \cdot \phi \cdot (\alpha - 1)}{\alpha (2\alpha - 1) - 2\alpha\phi(1 - 2\alpha)} \quad (15)$$

(reminder: $0 < \alpha < 1$, $0 < \phi < 1$)

Substituting equation 15 in 10 and 12, we obtain:

$$n_2 = \left[\left(\frac{w_1 \phi (\alpha - 1)}{\alpha (2\alpha - 1) - 2\alpha\phi(1 - 2\alpha)} \right)^{\alpha - 1} \cdot \frac{\mu A \alpha}{P_r^\alpha} \right]^{\frac{1}{2\alpha(\alpha - 1) + 1}} \quad (16)$$

$$P_r \cdot r = R\&D = \left[\left(\frac{\alpha(2\alpha - 1) - 2\alpha\phi(1 - 2\alpha)}{w_1 \phi (\alpha - 1)} \right)^\alpha (\mu A \alpha)^{2\alpha - 1} \right]^{\frac{1}{2\alpha(\alpha - 1) + 1}} P_r^{\frac{2\alpha^3 + 3\alpha^2 - 3\alpha + 2}{2\alpha^2 - \alpha + 1}} \quad (17)$$

Dividing equation 15 over equation 17:

$$\frac{w_2}{P_r r} = \left[\left(\frac{w_1 \phi (\alpha - 1)}{\alpha (2\alpha - 1) - 2\alpha\phi(1 - 2\alpha)} \right)^{\alpha(2\alpha - 1) + 1} (\mu A \alpha)^{1 - 2\alpha} \right]^{\frac{1}{2\alpha(\alpha - 1) + 1}} P_r^{\frac{(\alpha - 2)[\alpha(2\alpha - 1) + 1]}{\alpha(2\alpha - 1) + 1}} \quad (18)$$

Substituting 15 in 13:

$$\pi = \left(\frac{w_2}{\mu\beta} \right)^{\frac{1}{\beta - 1}} (\mu - w_1) - \left[(\mu A \alpha) \left(\frac{w_1 \phi (\alpha - 1)}{\alpha (2\alpha - 1) - 2\alpha\phi(1 - 2\alpha)} \right) \right]^{\alpha(2\alpha - 1)} P_r^{\frac{1}{2\alpha(\alpha - 1) + 1} \frac{-\alpha^2(2\alpha - 1)}{2\alpha^2 - \alpha + 1}} \quad (19)$$

D. Discussion

Transforming equations 15, 16, 17 and 18 into logarithms, leads us to the system of equations that allow us to estimate endogenous variables (at the LHS of each equation) as functions of the exogenous variables (on the RHS of each equation):

$$\log w_2 = \log w_1 + \log \phi + C + \varepsilon_1 \quad (20)$$

Where C is a constant:

$$C = \log \frac{\alpha - 1}{\alpha (2\alpha - 1) - 2\alpha\phi (1 - 2\alpha)}$$

$$\log n_2 = \frac{\alpha - 1}{2\alpha (\alpha - 1) + 1} \cdot [\log w_1 + \log \phi] + \frac{1}{2\alpha (\alpha - 1) + 1} \cdot [\log \mu + \log A] + K_1 + \varepsilon_2 \quad (21)$$

Where

$$M = \frac{\alpha - 1}{2\alpha (\alpha - 1) + 1}$$

$$J = \frac{1}{2\alpha (\alpha - 1) + 1}$$

$$K_1 = \frac{1}{2\alpha (\alpha - 1) + 1} [\log \alpha + (\alpha - 1) \log C] - \frac{\alpha}{2\alpha (\alpha - 1) + 1} \cdot \log p_r$$

K_1 and C are constants (i.e. p_r , price of research capital, is constant across firms)

$$\log p_r \cdot r = \log R\&D = \frac{-\alpha}{2\alpha (\alpha - 1) + 1} \cdot [\log w_1 + \log \phi] + \frac{2\alpha - 1}{2\alpha (\alpha - 1) + 1} \cdot [\log \mu + \log A] + K_2 + \varepsilon_3 \quad (22)$$

Where:

$$Q = \frac{-\alpha}{2\alpha (\alpha - 1) + 1}$$

$$T = \frac{2\alpha - 1}{2\alpha (\alpha - 1) + 1}$$

$$K_2 = \frac{1}{2\alpha(\alpha-1)+1} [(2\alpha-1) \cdot \log \alpha - \alpha \cdot \log C] + \frac{2\alpha^3+3\alpha^2-3\alpha+2}{2\alpha^3-\alpha+1} \cdot \log p_r$$

K_2 is a constant (i.e. p_r , price of research capital, is constant across firms)

Dividing equation 15 over equation 17:

$$\log \frac{w_2}{R\&D} = \log WRD = \frac{\alpha(2\alpha-1)}{2\alpha(\alpha-1)} \cdot [\log w_1 + \log \phi] + \frac{1-2\alpha}{2\alpha(\alpha-1)} \cdot [\log \mu + \log A] + K_3 + \varepsilon_4 \quad (23)$$

Where:

$$U = \frac{\alpha(2\alpha-1)+1}{2\alpha(\alpha-1)+1}$$

$$V = -T$$

$$K_3 = \frac{1}{2\alpha(\alpha-1)+1} \left[(1-2\alpha) \cdot \log \alpha + (\alpha(2\alpha-1)+1) \cdot \log \left(\frac{\alpha-1}{\alpha(2\alpha-1)-2\alpha\phi(1-2\alpha)} \right) \right] + \frac{(\alpha-2)[\alpha(2\alpha-1)+1]}{\alpha(2\alpha^2-1)+1} \log p_r$$

K_3 is a constant (i.e. p_r , price of research capital, is constant across firms)

E. Expected signs

All coefficients in equations 21 to 23 are elasticities.

Expected signs and dimensions of elasticities:

- $M < 0$; as $\alpha \rightarrow 1$, $|M| < 1$ (inelastic); and as $\alpha \rightarrow 0$, $|M| > 1$ (elastic);
- $J > 1$ (elastic);
- $Q < 0$; as $\alpha \rightarrow 1$, $|Q| > 1$ (elastic) and as $\alpha \rightarrow 0$, $|Q| < 1$ (inelastic);
- $-1 < T < 1$, $|T| < 1$ (inelastic);
- $U > 1$ (elastic);
- $-1 < V < 1$, $|V| < 1$ (inelastic)

Comparing their dimensions:

- $J > T$ and $J > V$
- $M < U$ and $Q < U$
- As $\alpha \rightarrow 1$, $|M| < |Q|$ and $T > V$
- As $\alpha \rightarrow 0$, $|M| > |Q|$ and $T < V$

— *Expected impact of the bargaining power of skilled workers:*

The bargaining power of skilled workers (Φ) is expected to have a negative impact (M) over skilled level of employment; it (M) could be inelastic or elastic depending on α 's tendency: when alpha tends to 1 the impact is expected to be inelastic; but when alpha tends to 0 the impact is expected to be elastic. Also, the bargaining power of skilled workers (Φ) is expected to have a negative impact (Q) over R&D spendings; depending on α 's tendency, this impact could be inelastic or elastic impact: it should be elastic when alpha tends to one and inelastic when alpha tends to zero. The former impact (M) is expected to be less elastic than the latter (Q) as alpha tends to one, and more elastic as alpha tends to zero. On the other hand, bargaining power of skilled workers (Φ) should have a positive and elastic impact (U) over the ratio of skilled workers' wages / R&D spendings and a positive and elastic unitary impact over the wages of skilled workers. The former impact is obviously expected greater than the latter.

— *Expected impact of the technological factor A (designs and technology non-embodied in capital, etc.):*

The technological factor A is expected to have a positive and elastic impact (J) over skilled level of employment. The impact of A is expected to be have inelastic (T) not only over R&D spendings and (V) over the ratio of skilled workers' wages / R&D spendings. The former impact (T) is expected to have contrary sign to the latter (V) and, in absolute terms, very similar impacts.

— *Expected impact of wages of unskilled workers:*

Same analysis as the one for the bargaining power of skilled workers.

— *Expected impact of the price of product:*

Same analysis as the one for technological factor A.

E Economic interpretation

— *Expected impact of the bargaining power of skilled workers:*

It is expected that the bargaining power of skilled workers (Φ) will have a positive and elastic impact U on the ratio of skilled workers' wages to R&D spending and a

positive and unit elastic impact on the wages of skilled workers. This means that greater bargaining power of skilled workers is expected to enhance, at least proportionally, skilled labor' wages and/or should cause a decrease in R&D spendings. The bargaining power of skilled workers would favor skilled labor wages to the detriment of firms' R&D spending. Increases in this ratio caused by an increase in the bargaining power of skilled workers, represent a skilled labor' appropriation of resources, which otherwise would have been devoted to R&D activities. This "turn over" of resources added to the estimation of the impact of bargaining power of skilled workers over their wages would be a measure of the subsequent creation of quasi-rents. U would measure this "turn over" of resources and the estimation of the impact of bargaining power of skilled workers over their wages would be a measure of the subsequent creation of quasi-rents. Also, this would be the reason why the bargaining power of skilled workers (ϕ) is expected to have a negative impact Q over R&D spendings (it also depends on α 's tendency: when α tends to one, Q should be elastic and when α tends to zero, Q should be inelastic).

The bargaining power of skilled workers (ϕ) is expected to have a negative impact M over the skilled workers level of employment. A rise in skilled workers hirings increases the wage-bill for skilled labor, so, costs would rise and, subsequently, profits be reduced. So it is sensible to think that, when skilled workers raise their bargaining power, it should be expected that maximizing-profits firms will hire less skilled workers. However, this impact differs (could be inelastic or elastic) depending on α 's tendency (to one or to nil)²³. For greater values of α (i.e. when α tends to one), the bargaining power of skilled workers is expected to cause an inelastic (in absolute terms) impact on skilled workers level of employment (i.e. the impact is expected to be elastic when α tends to zero). These different kinds of impacts mean that as skilled workers become more productive it is expected a lower decrease in the level of skilled workers. So, when skilled workers are more influential the decrease in the level of skilled employment is expected to be lower, assertion which seems quite reasonable.

— *Expected impact of the technological factor A (designs and technology non-embodied in capital, etc.):*

The technological factor A is expected to have a positive and elastic impact J over skilled workers' level of employment. Innovative firms rely in skilled workers' abilities to learn and innovate (non-innovative firms would rely less in skilled workers) and this could be the reason to expect the positive and elastic impact skilled workers' level of employment.

On the other hand, the impact of A is expected to be inelastic -in absolute terms- not only over R&D spendings but over the ratio of skilled workers' wages / R&D spendings. These impacts, T and V , have very similar impacts over R&D and w_2 /R&D but with opposite signs depending on α 's tendency. When α (the skilled labor'

²³ α measures the responsiveness of product percentual variations respect to skilled labor times R&D spendings percentual variations (i.e. the elasticity of production respect to skilled labor times R&D spendings = skilled labor' research productivity).

research productivity) tends to one, A 's impact over $w_2/R\&D$ is expected to be negative (and inelastic) and, on the contrary, A 's impact over $R\&D$ is expected to be positive (and also inelastic). The economic interpretation is that the technology factor increases complement any $R\&D$ when the skilled labor' research productivity tends to increase. Since the model yields that skilled workers wages are not dependent of the technology factor, T is just the inverse of V .

— *Expected impact of wages of unskilled workers:*

Unskilled workers' wages have the same elasticities with respect to bargaining power as skilled workers. Unskilled workers' wages constitute the available or alternative wages that skilled workers obtain in case of a delay in bargaining. Hence, the difference between the bargained wage and the available wage in case of a bargaining breakdown is the *cost of opportunity of bargaining*. When this cost of opportunity decreases it is expected to have an elastic and positive impact over the ratio of skilled workers' wages to $R\&D$ spending and a positive and elastic unitary impact over the wages of skilled workers.

On the other hand, decreases in the cost of opportunity are expected to have negative impacts over both $R\&D$ spendings and also the level of employment of skilled workers.

— *Expected impact of the price of product:*

This has the same elasticities as the technological factor A . The elasticities respect to the price of product measures the impact of demand shocks on the firm.

V. ESTIMATION

A. Methodology

I will be using ordinary least squares (OLS). According to the Gauss-Markov Theorem, this method yields for elasticities the best linear unbiased estimators.

These estimators have the minimum variance under the following assumptions:

1. The equation is correctly specified (linear) and all the relevant variables are in the equation.(no omitted variables or misspecification)

2. $E(\epsilon_i) = 0 \forall i$ (zero mean error)

3. $\text{Var}(\epsilon_i) = E(\epsilon_i^2) = \sigma^2 \forall i$ (constant variance or homoskedasticity)

4. $\text{Cov}(\epsilon_i, \epsilon_j) = E(\epsilon_i, \epsilon_j) = 0 \forall i \neq j$

5. Exogenous variables are fixed and the matrix that forms the exogenous variables has full rank

B. The data

During the second semester of 1996, the National Planning Department of Colombia and The National Institute of Science (Colciencias) developed the Inquest of Technological Development in the Colombian Industrial Establishment in order to compile precise and detailed information of the technological situation of Colombia (specifically in the manufacturing sector). During this period, 885 establishments of all industrial sectors (except the tobacco sector) were polled. The survey universe is of 4500 industrial firms with more than 20 workers, distributed in 26 sectors industrial activity.

The general objective of the survey is to characterize the dynamics of technology in Colombian industries, to identify the determinant factors of technological development and to support technological policy formulation. All definitions of innovation, R&D, and technological training activities in the survey questionnaire are based on the *Frascati Manual* (OCDE, Paris, 1994). The measurement of variables is the same than in the estimation in chapter 3.

C. Interpretation of estimators of equation 20 (wages of skilled labor)

The estimation of the elasticity of skilled workers wages respect to unskilled wages and the bargaining power of skilled workers yields that only postgraduates-wages have a significant association with bargaining-power-of-skilled-workers (Table 2). It is positive as expected (estimated value = 0.25) but it is not a unitary elasticity as expected. So, a 1% increase in bargaining power of the skilled workers leads to a 25% increase in postgraduates' wages (*ceteris paribus*). Neither technicians nor professional wages estimations yield a significant association with bargaining-power-of-skilled-workers, nevertheless, they are, as expected, associated positively and significantly (both at 1%) with wages of the unskilled workers. Increases in the wages of all skilled workers are strongly associated positively and significantly (10%) with the increases of wages of the unskilled workers, as expected. 1% raises in unskilled workers' wages has impact over 50% in skilled workers' wages (*ceteris paribus*).

TABLE 2
Summary of main results of Eq. 20

<i>Elasti-Cities Estim.</i>	Respect to w_1	Expect.	Signif.	Respect to ϕ	Expect.	Signif.
Wages of technicians	0.60	Positive✓ Elastic Unitary☒	1% Obs: 486	0.06	Positive✓ Elastic Unitary☒	low Obs: 486
Wages of profess.	0.50	Positive✓ Elastic Unitary☒	1% Obs: 477	0.02	Positive✓ Elastic Unitary☒	low Obs: 477
Wages of postgrad.	0.54	Positive✓ Elastic Unitary☒	1% Obs: 161	0.25	Positive✓ Elastic Unitary☒	10% Obs: 161

Source: Author's calculations

D. Interpretation of estimators of equations 21 to 23 (employment of skilled labor, r&d spendings and wages of skilled workers / R&D spendings ratio)

In this section, by the method of ordinary least squares (OLS), we obtain the estimation (BLUE) of the elasticities M and J (dependent variable: level of employment of skilled workers), U and V (dependent variable: ratio of wages of skilled workers / R&D spendings ratio), and, finally, Q and T (dependent variable: R&D spendings), for equations 20 to 22, at each skill level: tec=technicians, pro=professionals and pos=postgraduates (Summary of results in tables 3 and 4).

TABLE 3
Summary of main results of Eq. 21, 22 and 23

<i>Elasti-Cities Estim.</i>	Respect to w_1	Expected	Signif.	Respect to ϕ	Expected	Signif.	Diagnostics
M – tec (n_2)	-0.13	Negative✓	low Obs: 173	0.52	Negative☒	5% Obs: 173	$R^2=0.48$ F: 40.2
M – pro (n_2)	0.49	Negative☒	1% Obs: 168	0.42	Negative☒	10% Obs: 168	$R^2=0.57$ F: 54.3
M – pos (n_2)	0.41	Negative☒	10% Obs: 73	0.07	Negative☒	low Obs: 73	$R^2=0.38$ F: 10.06
U - tec (w_2 / R&D)	0.02	Positive✓ Elastic☒	low Obs: 80	0.13	Positive✓ Elastic☒	low Obs: 80	$R^2=0.30$ F: 8.4
U - pro (w_2 / R&D)	-0.33	Positive☒ Elastic☒	low Obs: 82	0.26	Positive☒ Elastic☒	low Obs: 82	$R^2=0.29$ F: 7.9
U - pos (w_2 / R&D)	-0.37	Positive☒ Elastic☒	low Obs: 40	1.19	Positive✓ Elastic✓	low Obs: 40	$R^2=0.16$ F: 3.19
Q (R&D)	0.69	Negative☒	low Obs: 89	0.04	Negative☒	low Obs: 89	$R^2=0.43$ F: 16.3

Source: Author's calculations - ✓ matches with estimation (i.e. according to expected) - ☒ does not match with estimation (i.e. not according to expected) - Obs: number of observations

TABLE 4							
Summary of main results of eq. 16, 17 and 18							
<i>Elasti-Cities Estim.</i>	Respect to w_1	Expected	Signif.	Respect to prod. Price	Expected	Signif.	Diagnostics
J - tec (n_2)	0.18	Positive✓ elastic☒	1% Obs: 173	0.30	Positive✓ elastic☒	1% Obs: 173	$R^2 = 0.48$ F: 40.2
J - pro (n_2)	0.24	Positive✓ elastic☒	1% Obs: 168	0.19	Positive✓ elastic☒	1% Obs: 168	$R^2 = 0.57$ F: 54.3
J - pos (n_2)	0.08	Positive✓ elastic☒	low Obs: 73	0.16	Positive✓ elastic☒	5% Obs: 73	$R^2 = 0.38$ F: 10.06
V - tec (w_2 / R&D)	-0.39	Inelastic (absolute terms)✓	1% Obs: 80	-0.14	Inelastic (absolute terms)✓	low Obs: 80	$R^2 = 0.29$ F: 7.9
V - pro (w_2 / R&D)	-0.34	Inelastic (absolute terms)✓	5% Obs: 82	-0.10	Inelastic (absolute terms)✓	low Obs: 82	$R^2 = 0.16$ F: 3.19
V - pos (w_2 / R&D)	-0.35	Inelastic (absolute terms)✓	low Obs: 40	-0.05	Inelastic (absolute terms)✓	low Obs: 40	$R^2 = 0.4$ F: 16.3
T - (R&D)	0.43	Inelastic (absolute terms)✓	1% Obs: 89	0.10	Inelastic (absolute	low Obs: 89	$R^2 = 0.30$ F: 8.4

Source: Author's calculation - ✓ matches with estimation (i.e. according to expected) - ☒ does not match with estimation (i.e. not according to expected) - Obs: number of observations

From Table 3, we obtain that almost all elasticity estimators (except four) have very low statistical significance. M-tec and M-pro (elasticities of employment-of-technicians-and-professionals respect to bargaining-power-of-skilled-workers) are inelastic, as expected, but have opposite sign to the (negative) expected one. The estimation yields values for elasticities of 0.52 and 0.42 respectively (both significant at 5%).

The estimates do not show any significant association between skilled workers' bargaining power, R&D spending, the ratio of skilled wages/R&D spendings, or the wages of technicians or professionals. This result contrasts with the rent-sharing results where at R&D spending had a significant association with technicians and professional workers. This will be discussed in the next section. Surprisingly, increases in the available wage in case of a bargaining breakdown (operators' wages i.e. unskilled workers) has a positive and significant (10%) impact over professional and postgraduate levels of employment (a negative impact was expected!). According to table 3, a 1% increase in the wages of unskilled workers has a positive impact (over 40%) on the levels of employment of professional and postgraduate workers (ceteris paribus).

From Table 4, we obtain that innovative activities such as designs and technology embodied in capital (represented in the technological factor A in the production function) are associated significantly with the levels of employment of all skilled workers (technicians (1%), professionals (1%) and postgraduates (5%)). The elasticities (0.18, 0.24, and 0.08 respectively) are, as expected, positive but, not as expected, inelastic. R&D spending elasticity with respect to the factor A is less than one (in absolute terms), as expected, and is positively and significantly (1%) associated to the technology factor A . We also can observe in Table 2 that the technological factor A is negatively and significantly (1%) associated to the ratios of technicians and professional wages/R&D spendings. Their values are inelastic (in absolute terms) as expected.

E. Comparison with estimates of rent-sharing test

The principal difference between the rent-sharing test and the latter results is that, under the former, R&D spendings seem to have a positive and significant impact over skilled workers (i.e. technicians and professionals) wages while under the new framework there seems to be no significant association. Hence, under rent-sharing theory skilled wages seem to have a significant R&D's rent content while under the new theory there seem to be no significant rent content. The cost of opportunity of bargaining²⁴ yields some striking results in both estimations. Increases in the wages of all skilled workers are in both analyses strongly associated positively and significantly (10%) with reductions in the cost of opportunity of bargaining (i.e. increases in the wages of unskilled workers). 1% decreases in the cost of opportunity of bargaining have impacts of over 50% in skilled workers' wages (*ceteris paribus*) under any of the two frameworks (i.e. rent-sharing or new theory).

Estimates of rent-sharing models yield a positive and significant association between skilled workers' wages and R&D spending. Estimations under a new theoretical framework do not confirm this result. Formerly, R&D spendings were used as an instrumental variable in order to deal with profits' endogeneity. Under the new framework R&D spending is no longer assumed exogenous²⁵, and so the relation between R&D spending and the wages of skilled workers is understood as a response of two endogenous variables linked by common exogenous variables. Future research should evaluate why endogenizing R&D spendings changes the results so radically. For example, an increase in an exogenous variable such as the bargaining power of skilled workers was expected to favor skilled labor wages to the detriment of firms' R&D spendings, and so the ratio R&D/skilled-workers'-wages was expected to increase. Increases in this ratio caused by an increase in the bargaining power of skilled workers, would represent a skilled labor' appropriation of resources, which otherwise

²⁴ The difference between the bargained wage and the available wage in case of a bargaining breakdown is the cost of opportunity of bargaining.

²⁵ In fact, R&D spendings are endogenized as part of the profit endogenization.

would have been devoted to R&D activities. This “turn over” of resources added to the estimation of the impact of bargaining power of skilled workers over their wages would be a measure of the subsequent creation of quasi-rents. But the estimate of bargaining power of skilled workers did not have the significance with respect to the expected. So R&D in the original rent-sharing model is associated with wages of skilled labor, but this result no longer holds if R&D is endogenized.

VI. CONCLUSIONS, FUTURE RESEARCH AND POLICY

The main objective of the dissertation was to determine the R&D's rent content in skilled workers' wages. Quasi-rents reduce firms' incentives to invest in R&D activities as workers appropriate R&D returns. Colombia's manufacturing industry has a small proportion (1/4) of firms investing in R&D. At present, the enhancement of both skills among the labor force and R&D activities are considered to be the solution for economic growth and competitiveness problems in less developed countries (LDCs). But if educational-level enhancements generate rents for workers then economic and educational policy-makers should be alerted that the medicine could turn out to be worse than the disease.

Estimates of rent-sharing models yield a positive and significant association between skilled workers' wages and R&D spendings. Estimations under a new theoretical framework do not confirm this result. Formerly, R&D spendings were used as an instrumental variable in order to deal with profits' endogeneity. Under the new framework R&D spending is no longer assumed exogenous²⁶, and so the relation between R&D spending and the wages of skilled workers is understood as a response of two endogenous variables linked by common exogenous variables. Future research should evaluate why endogenizing R&D spendings changes the results so radically. For example, an increase in an exogenous variable such as the bargaining power of skilled workers was expected to favor skilled labor wages to the detriment of firms' R&D spendings, and so the ratio R&D/skilled-workers'-wages was expected to increase. Increases in this ratio caused by an increase in the bargaining power of skilled workers, would represent a skilled labor' appropriation of resources, which otherwise would have been devoted to R&D activities. This “turn over” of resources added to the estimation of the impact of bargaining power of skilled workers over their wages would be a measure of the subsequent creation of quasi-rents. But the estimate of bargaining power of skilled workers did not have the significance with respect to the expected. So R&D in the original rent-sharing model is associated with wages of skilled labor, but this result no longer holds if R&D is endogenized.

There is another result that raises an interesting issue. The estimation of the elasticity of the bargaining power of skilled workers had a significant impact over the wages of postgraduates in an important way: a 1% increase in bargaining power

²⁶ In fact, R&D spendings are endogenized as part of the profit endogenization.

of the skilled workers²⁷ significantly leads to a 25% increase in postgraduates' wages. According to social psychology science, bargaining power depends mostly on how parties use information on each other's dependence to estimate the utility of an influence attempt. The positive and significant impact of bargaining power of skilled workers over postgraduates' wages leads us to conclude that postgraduates' workers awareness of the reliance of firms on skilled workers to undertake R&D projects (or even if skilled workers did not had information on this reliance), seems to leave them in a better-position to demand pay raises. This conclusion could be very useful as a guide for future research in the field.

Other interesting issue are: the cost of opportunity of bargaining²⁸ yields striking results under both frameworks. Increases in the wages of all skilled workers are — under both frameworks- strongly associated (positively and significantly (10%)) with reductions in the cost of opportunity of bargaining for skilled workers (i.e. increases in the wages of unskilled workers). One percent decreases in the cost of opportunity of bargaining for skilled workers have impacts of over 50% on skilled workers' wages (*ceteris paribus*) under either of the two frameworks (i.e. rent-sharing or new theory). Future research should deepen the analysis of how the cost of opportunity of being an innovator (or, in this context, being a skilled worker in a firm with R&D projects) could affect the worker's and the organization's decisions to undertake R&D projects. In other words, how do increases in the wages of alternate activities to innovation affect both firms' decisions to undertake R&D projects and also skilled workers' wages in these firms? Which are these alternate activities for skilled workers? Bearing these questions in mind, the rent-seeking approach could provide interesting insights for future research.

Economic policy recommendations are quite straightforward. Policy makers should take into account that educational-level enhancements could generate rents from R&D to skilled workers. R&D and education complement each other. This fact leads many economic advisors in LDCs to recommend educational-level enhancement as a *panacea* for all kinds of development problems (e.g. economic growth and competitiveness). Nonetheless, educational and technological policies should be alerted about the new insights that rent-sharing studies results. R&D and education could complement each other, under certain circumstances, but could be antagonists when quasi-rents arise among skilled workers' wages. Policy makers are aware of the virtues that educational enhancement has, but *are they aware of the risks society incurs with such policies?*

²⁷ We must bear in mind that the dissertation introduced a new measure of bargaining power (bargaining power = index of innovativeness of the firm).

²⁸ Cost of opportunity of bargaining = difference between the bargained wage and the available wage in case of a bargaining breakdown = wage differential between skilled and unskilled workers.

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