Employment level, hours of work and labor adjustment cost in the Brazilian industry*

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This paper builds a microeconomic model of determination of employment and hours of work in the long-run. This model is used to specify a short-run equation for the ratio employment/hours of work per person in order to capture the existence of labor adjustment cost in the Brazilian industry. Furthermore, we looked for insights with respect to the substitutability between hours of work per person and employment. The same equation was used in two levels of aggregation (Brazil and São Paulo state) for different sectors of the manufacturing industry, to check the specification adopted. We found that, in general, the specification works quite well, but finer statistical tests showed the necessity of additional work to understand the results for specific sectors.

1. Introduction; 2. The determination of optimal levels of employment and hours of work per person in the long-run; 3. Labor adjustment costs and the equation to be estimated; 4. The empirical results; 5. Final observations.

1. Introduction

Most studies about labor demand or other issues related to Brazilian industry have produced poor results. One of the basic reasons is the absence of a rigorous treatment of the role of hours of work per person in the determination of the effective amount of labor employed in the production process.

A significant part of the labor economics literature in the 60's and 70's focused on the role of hours of work per person as a short-run adjustment variable of the total labor employed in the production process when output varies. In general, the models used for dealing with this question do not look

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carefully at the substitutability between employees and labor hours.[1] In this paper we will try to deal more carefully with this point.

This paper follows three steps. The first one is to build a model that gives insight into the determination of the levels of employment and labor hours in a situation where the costs of adjustment of the labor force are not relevant (long-run). At this stage we will try to explain some stylized facts, at least for the Brazilian industry, as the relative invariability of average labor hours in the long-run. The section 2 presents this model.

The second step is taken in section 3. There, we will introduce labor adjustment costs into the model, in order to be able to specify an equation to be estimated. This equation will try to capture both the substitutability between employees and hours of work per person and the adjustment costs of the labor force.

In section 4, the equation developed in section 3 will be applied to the Brazilian industry at the national level and at the state level, using São Paulo. The basic reason for this comparison is to test the reasonability of the specification chosen to capture the labor adjustment costs, since we should expect these costs to be higher for industries based in São Paulo than for the nation as a whole, since the most modern industries in the country are located in this state. But it also extends the approach to another data-base, enabling us to better evaluate the specification adopted.

Finally, it should be noted that this is the first paper to use the new IBGE/PIM-DG, a monthly data-base for Brazilian industry, and that a substantial part of the work involved calculating and selecting the right variables from this and other data-bases. So, the sectors chosen to be studied were those wherein we would be able to homogenize the data among different levels of aggregation and different data-bases. Section 5 concludes this paper.

2. The determination of optimal levels of employment and hours of work per person in the long-run[2]

In this section we will build a cost minimization model at the microeconomic level. The basic assumption is that the level of output is fixed exogenously and the firm determines the number of employees and the amount of hours contracted with each of them, given the costs of inputs and the format of the production function.

1. Some good exceptions are Rosen (1968) and Ehrenberg (1971).

2. This model was inspired by the contributions of Ball & St. Cyr (1967), Bell (1982), Brechling (1965), Brechling & O'Brien (1967), Ehrenberg (1971), Fair (1969), Hart & Sharot (1978), Nickell (1986), Rosen (1968) and Tinsley (1971).

Another important assumption is the absence of adjustment costs of the labor force. Thus, this model is a long-run model in the sense that the firm can vary the level of employment freely, since all variations in the output level are known to be permanent. The uncertainty about the type of output variation (permanent or temporary) will be introduced in the next section, where we will also consider the existence of adjustment costs of labor.

2.1 The production function

The specification of the production function that includes employees and hours of labor is not uniform in the economic literature. Each study makes different assumptions concerning:

– the degree of substitutability between "capital services" and "labor services" and between hours of work per person and employment (the basic determinants of "labor services");

– the type of marginal return of each production factor;

– the existence of decreasing, increasing or constant returns to scale.

The discussion about the degree of substitutability between capital and labor is very complex since it hinges on the different ways capital can replace labor in the production process. For instance, we should expect that a variation in the number of labor hours, for a given level of employment, will affect the number of machines used in the production process as well as the amount of time that each machine is in use. We should, further, expect that such a variation will differ from the one caused by a change in the level of employment for a given size of the daily labor hours.

But we are not interested here in the substitutability between the labor factor and the capital factor. Some works emphasize this, but then neglect the substitutability between labor hours and employment[3] in order to build a feasible equation to be estimated. In this model we will make the crucial assumption that the interaction between capital and labor does not change the logic behind the determination of the relation between employment level and labor hours.

In order to simplify the model, we will assume that the production process associates one unit of capital to a fixed number of workers, *i.e.*, the ratio of capital to workers is constant through time. The objective is enabling us to focus on the determination of the ratio of employment to hours of work per person, thereby avoiding the complications caused

[3] See for instance Rosen (1968).

by a more general treatment of the substitutability between capital and labor.

No assumptions about the marginal and scale returns of the production function will be made, since they are not necessary in the context in which we are working.[4] On the other hand, we will make very specific assumptions related to the determination of labor services.

The most common assumption is that the total number of hours employed is a good proxy for labor services. The most used specification is:[5]

$$X_t = A\, e^{rt} (N_t \cdot H_t)^{\alpha} = A\, e^{rt} (L_t)^{\alpha} \tag{2.1}$$

where: X_t = production level;
A = positive constant;
N_t = employment level;
H_t = average labor hours of employees;
L_t = total labor hours.

This approach assumes that any combination of labor hours and number of employees generates the same amount of services of labor. We do not accept this hypothesis. It is reasonable to assume that the level of output produced using one employee working 12 hours per day should be different from the level of output produced using two employees six hours per day or three employees four hours per day.

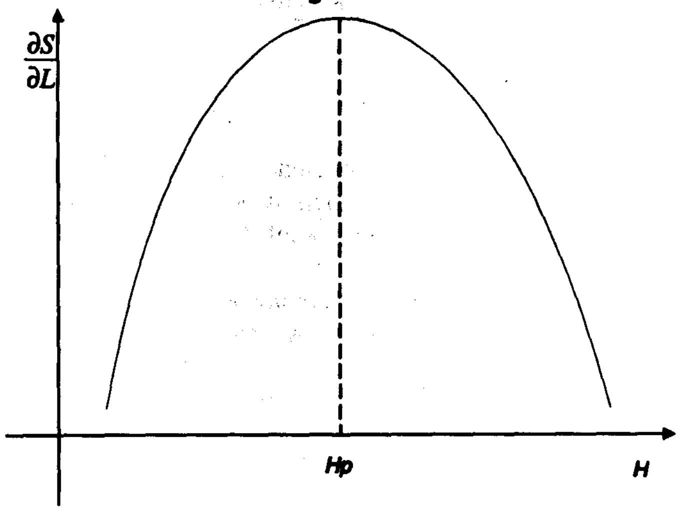
In other words, for lower level of labor hours, the marginal productivity of each employee is low, since there is a minimum amount of time needed for the workers to warm up. Furthermore, worker's productivity increases with the time he works because the fixed amount of time spent on beginning and finishing production, on meals, on instructions and so on, becomes relatively smaller.[6] On the other hand, an increase in labor hours increases worker's fatigue and diminishes his concentration in the production process. We assume that at some level of hours of work per

4 It is striking, in some way, the importance attributed to this kind of assumptions by the traditional literature on labor adjustment costs. See, for instance, Ball & St. Cyr (1966), Brechling (1965), Ireland & Smith (1970), Leslie & White (1980), Smith & Ireland (1977), Soligo (1966) and Waud (1968), among others.

5 See Ball & St. Cyr (1967), Brechling & O'Brien (1967) and Fair (1969). Others included capital stock in the production function. See, for instance, Dhrymes (1966), Ireland & Smith (1969) and Soligo (1966) that proposed a production function like:
$X_t = A\ e^{rt}(N_t H_t)^{\alpha}\ (K_t)^{\beta}$, where K = capital stock.

6 See Feldstein (1967).

Figure 2.1



person, both effects cancel each other and each worker achieves his maximum productivity.[7]

So, the labor services function here assumed can be represented as:

$$S = S\ (L, H) = J(H)\,.\,L \tag{2.2}$$
$$J'(H) > 0, \text{ if } H < H_P$$
$$J'(H) < 0, \text{ if } H > H_P$$
$$J'(H) = 0, \text{ if } H = H_P$$
$$J''(H) < 0$$

where S is the total labor services employed in the production process. Then, if the production function is represented as [8]

$$F(S(H,L)) = A \cdot S^{\alpha} \tag{2.3}$$

the average and marginal products of the total labor hours are:

7 For some alternative ways of modeling the interaction between hours of labor and productivity of a stock of employees see Brechling (1965), Feldstein (1967), Rosen (1968), Ehremberg (1971), Craine (1973), Leslie & White (1980) and Bell (1982). With the exceptions of Ehremberg (1971) and Rosen (1968), the other alternatives are too simplistic and not so realistic. In these two other papers the function $S(N,H)$ is too general for our purposes.

8 Notice that we assumed a fixed coefficient of production between men and capital and that capital is the abundant production factor.

$$APL = \frac{F(S)}{L} = \frac{A \cdot (J \cdot L)^{\alpha}}{L} = A \cdot J^{\alpha} \cdot L^{(\alpha - 1)} \tag{2.3a}$$

$$MPL = \frac{\partial F(S)}{\partial L} = A \cdot \alpha \cdot J^{\alpha} \cdot L^{(\alpha - 1)} \tag{2.3b}$$

Looking at these equations we conclude that the marginal and average productivities of a given total labor hours is positively correlated to the $J(\cdot)$ function. So they reach their maximum point at $H = H_P$. Figure 2.1 represents the $J(\cdot)$ function.

To better understand the relationship among hours of work per person, level of employment and total labor hours, we should compare an "iso-labor services" curve with an "iso-total labor hours" curve. In (2.4) and (2.5) we show respectively the iso-labor services and its slope:

$$N = \frac{\bar{S}}{J(H) \cdot H} \tag{2.4}$$

$$\left.\frac{dN}{dH}\right|_{S = \bar{S}} = -\frac{N}{H} \cdot \left[\frac{J'(H) \cdot H + J(H)}{J(H)}\right] \tag{2.5}$$

The iso-total labor hours has an inclination equal to:

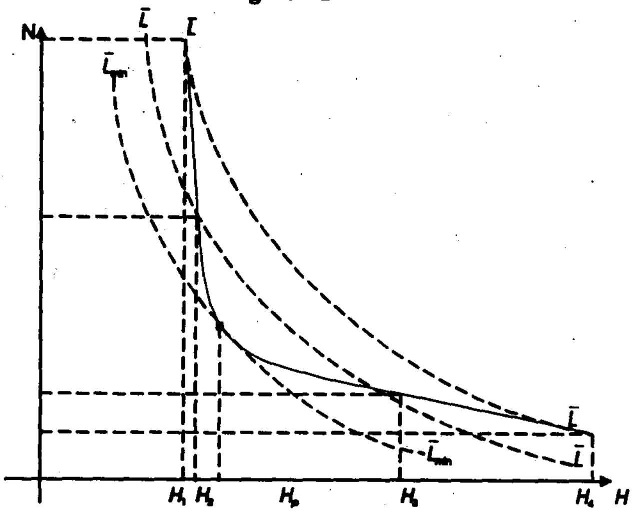
$$\left.\frac{dN}{dH}\right|_{L = \bar{L}} = -\frac{\bar{L}}{H^2} = -\frac{N}{H} \tag{2.6}$$

So, $H = H_P$, $\left.\frac{dN}{dH}\right|_{S = \bar{S}} = \left.\frac{dN}{dH}\right|_{L = \bar{L}}$, since $J'(H_P) = 0$, and

$$\left|\frac{dN}{dH}_{S = \bar{S}}\right| \gtrless \left|\left.\frac{dN}{dH}\right|_{L = \bar{L}}\right| \text{ if } H \lessgtr H_P, \text{ since } J'(H_P) \gtrless 0.$$

These curves are represented in figure 2.2. Notice that the minimum iso-total labor hours that generates a given amount of labor services is tangent to the correspondent iso-labor services at $H = H_P$. If we want to increase the labor hours per person from this point, keeping the labor services constant, we have to decrease the level of employment proportionately less. This increases the total labor hours employed in the production process. In figure 2.2 this corresponds to a movement from L_{min} to L' and from H_P to H_3. If H increases again, L has to increase to produce the same amount of labor services (from L' to L). If $H < H_P$,

Figure 2.2



an increase in *H* diminishes the total labor hours needed to produce the same amount of labor services.[9]

2.2 The cost equation

The first step in characterizing the cost equation of a firm is to determine the way labor is remunerated. We will assume that the normal hours of work per person (*Ho*) is not divisible in the sense that the firm has to pay (*Wo. Ho*) for each employee even if he works less than *Ho* (and *Wo* is the normal hourly wage). This institutional characteristic is not so relevant here; but further development of this model, comparing this system with another.one presenting a divisible normal remuneration, is very relevant in analyzing labor storage problems as exposed in Fair (1969).[10]

Other cost variables are the prices of intermediate products. We will assume that the cost of these inputs is a positive function of the total

[9] The convexity of iso-labor services curve can be demonstrated for $H > Hp$ if we differentiate (2.5) with respect to *H*:

$$\frac{d\left[\frac{dN}{dH}\right]}{dH} = -\frac{N(J''\,.\,H+2\,.\,J')}{J.H} + \varepsilon^2_{3H}\,.\,\frac{N}{H^2} > 0$$

since the second term is always positive and $J' < 0$ in this region. If $H < Hp$ we need $J' < -J''.(H/2)$ to have convexity.

[10] Just Ball & St. Cyr (1967) uses this kind of formulation, also adopted here because it represents better the Brazilian institution.

labor hours used in the production function. The idea of this assumption is to use the total labor hours as an index of activity level inside the firm. In this model, this assumption is true since machines and workers are combined in fixed proportions and, then, the total capital hours is the same as the total labor hours. So, an increase in labor hours implies higher utilization of non-labor inputs. The hypothesis of this model simply makes this relationship a linear one.[11] The cost equation is then:

$$C = WC + \bar{P}c_i \cdot I_i \tag{2.7}$$

where:

WC = total labor cost;
$\bar{P}c_i$ = unit price of intermediary input i;
Ii = total amount of input used in the production process.

Writing $I_i = o_i \cdot L$ and considering $o_i = \bar{o}_i$ = constant, we may focus on just $Pc_i = \bar{o}_i \;.\; \bar{P}c_i$. So, any change in this variable should be caused by a change in price. The total labor cost can be written as:

$$CW = \begin{cases} \{FC + Wo \cdot Ho\} \cdot N, & \text{if } H \leq Ho \\ \{FC + Wo \cdot Ho + Wo \cdot (1+b) \cdot (H - Ho)\} \cdot N, & \text{if } H > Ho \end{cases} \tag{2.8}$$

where,

FC = fixed cost per employee. These are fixed *labor* costs, such as maintenance of a day-care center for children, social security contributions by the firms, annual bonus, and all other expenditures that are independent of the number of hours of work per person;
Ho = normal hours of work per person (determined institutionally);
Wo = remuneration of one normal labor hour;
b = additional percentage of Wo paid for each extra hour of work. We are assuming that this percentage is constant.[12]

[11] We will not consider depreciation costs and other strict capital related costs, as some fixed costs, since these should not influence the ratio of employment to hours of work per person.

[12] This is not a crucial assumption. If b was a function of H-Ho this would just imply that the optimal hours of work per person (H^*) would be more sensitive to cost variables (see next section for the definition of H^*).

The corresponding iso-cost is represented in figure 2.3.[13] This curve has two parts with slopes given by (2.9) and (2.10). Given that extra hours of work are more expensive, the slope of the right portion of this curve is bigger than the left portion.

$$\left.\frac{dN}{dH}\right|_{c=\bar{c}} = -N \cdot \left[\frac{Pc}{FC + Wo \,.\, Ho + Pc \,.\, H}\right], \text{ if } H \leq Ho \tag{2.9}$$

$$\left.\frac{dN}{dH}\right|_{c=\bar{c}} = -N \cdot \left[\frac{Wo \,.\, (1+b) + Pc}{FC + Wo \,.\, Ho + Wo \,.\, (1+b) \,.\, (H-Ho) + Pc \,.\, H}\right],$$

$$\text{if } H > Ho \tag{2.10}$$

If the consumption of non-labor inputs was not related to the total labor hours used in the production process, the left part of the iso-cost curve would be a horizontal line. If the normal hours of work per person were divisible, we would have this negative slope anyway. The introduction of the relationship between intermediary input and total labor hours would just make the left portion of this iso-cost more inclined, like the dotted portion of figure 2.3.[14]

2.3 The cost minimization process[15]

For a given level of output, the representative firm will determine the optimal combination of employment level and labor hours that minimize the production costs:

[13] From now on we will assume that there is just one relevant intermediary input.

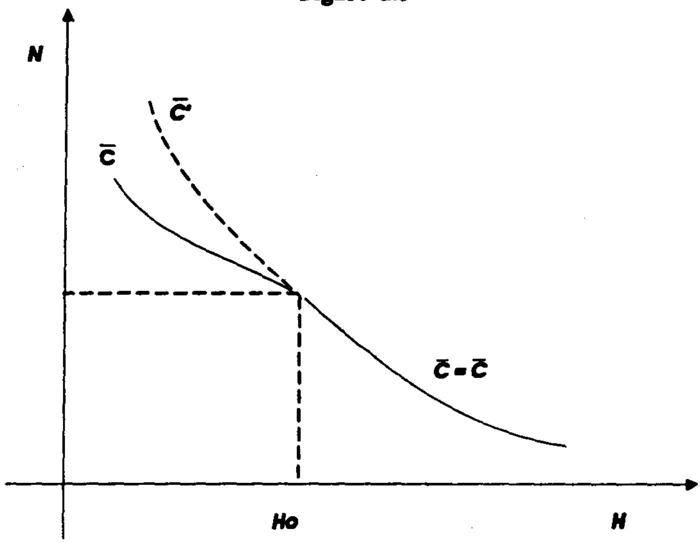
[14] We may show the iso-cost convexity by differentiating (2.9) and (2.10) with respect to H:

$$\left.\frac{d\left[\frac{dN}{dH}\right]}{dH}\right|_{c=\bar{c}} = \frac{P_c^2 \,.\, N}{(FC + Wo \,.\, Ho + Pc \,.\, H)^2} > 0, \text{ if } H < Ho$$

$$\left.\frac{d\left[\frac{dN}{dH}\right]}{dH}\right|_{c=\bar{c}} = \frac{(Wo.(1+b)+Pc).N^2}{[FC - Wo \,.\, b \,.\, Ho + (Wo \,.\, (1+b) + Pc) \,.\, H]} > 0, \text{ if } H > Ho.$$

[15] We will assume in this section that the iso-labor services curve is more convex than the iso-cost curve. This hypothesis guarantees an interior and stable solution.

Figure 2.3



$$\min_{N,H} \cdot C = WC + Pc \cdot H \cdot N$$

$$s.t.\ F\,(S\,(H,L)) \geq X = \overline{X}$$

At the optimum, the slope of both the iso-cost and the iso-labor services either will be the same or will be in the kink of the iso-cost curve. So, depending on the value of the parameters, we can have three distinct optimum points. They can be represented by the three equations below:

$$\left[\frac{Pc\,.\,H}{FC + Wo\,.\,Ho + Pc\,.\,H}\right] = \left[\frac{J'(H)\,.\,H + J(H)}{J(H)}\right] = \varepsilon_{S,H} = \text{elasticity of labor}$$

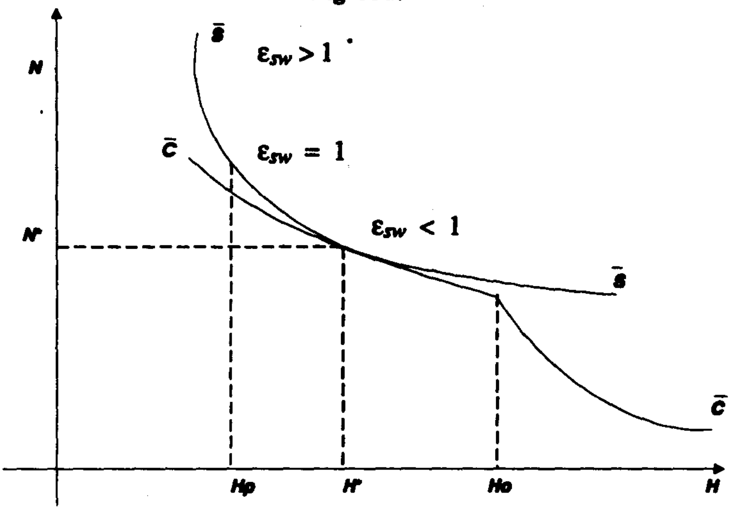
services with respect to hours of work per person, if $H < Ho$ (2.11)

$$\left[\frac{(Wo\,.\,(1+b) + Pc)\,.\,H}{FC + Wo\,.\,Ho + Wo\,.\,(1+b)\,.\,(H - Ho) + Pc\,.\,H}\right] = \varepsilon_{S,H}\text{, if } H > Ho \quad (2.12)$$

$$\left[\frac{Pc\,.\,H}{FC + Wo\,.\,Ho + Pc\,.\,H}\right] < \varepsilon_{S,H} <$$

$$< \left[\frac{(Wo\,.\,(1+b) + Pc)\,.\,H}{FC + Wo\,.\,Ho + Wo\,.\,(1+b)\,.\,(H - Ho) + Pc\,.\,H}\right]\text{, if } H = Ho \quad (2.13)$$

Figure 2.4



Analyzing these possibilities yields many insights:

1) By (2.11) we can state that it is possible to have one situation where $H^* < Ho$ if $\varepsilon_{S,H} < 1$ ($H > Hp$). In this case, it is possible that the savings from a diminution in the consumption of non-labor inputs when H decreases from Ho to $H < Ho$ (since in this region the total labor hours needed to produce X units of output decreases when H decreases) compensates the firms expenditures for more hours of labor than they are really using. We generate another explanation for the existence of "labor storage" that does not depend on the existence of labor adjustment costs.[16] This situation is depicted in figure 2.4.

The sensitivities of H (and, of course, N in the opposite direction) to changes in the cost variables, at this optimum point are:

$$\frac{dH}{dPc} = -\frac{N \,.\, H^2 \,.\, J'}{C.(J'' \,.\, H+2J')} < 0, \text{ because } J' \text{ and } J'' < 0;$$

$$\frac{dH}{dFC} = -\frac{N \,.\, (HJ'+J)}{C.(J'' .H+2J')} > 0$$

$$\frac{dH}{dHo} = -\frac{N.\, Wo \,.\, (HJ'+J)}{C.(J'' .H+2J')} > 0$$

16 Fair (1969) was the first to formally relate labor adjustment cost and "storage of labor".

$$\frac{dH}{dWo} = - \frac{N.Ho.(HJ'+J)}{C.(J''.H+2J')} > 0$$

That is, if Wo or Ho increases, the total cost of the hours employed but not dedicated to production augments and then the firm will increase H and reduce N.[17] If FC increases it becomes cheaper for the firm to "produce" the same level of labor services with less employment and more hours of work per person.

2) The firm could be hiring more labor hours than Ho if the productivity of labor hours is high enough and/or if their marginal cost, when compared with the marginal cost of a certain level of employment, is low enough to compensate for the higher cost of these additional hours. Rewriting (2.12), we see that H^* can be bigger than Ho at any level of $\varepsilon_{S,H}$. The optimal point will be:

a) $H^* > Hp$, if $FC > Wo \cdot b \cdot Ho$

b) $H^* = Hp$, if $FC = Wo \cdot b \cdot Ho$

c) $H^* < Hp$, if $FC < Wo \cdot b \cdot Ho$

as is shown in figure 2.5 a, b and c.

The sensitivity of H to changes in cost variables is very intuitive, as shown in equations (2.13). An increase in FC, a decrease in Wo, and a decrease in b augment the relative marginal cost of the employment level. This motivates the firm to increase H and reduce N. The effect through Ho is more curious: *a decrease in Ho* acts like an increase in FC but leaves the marginal cost of extra hours of work intact; *this makes H to increase*. So, additionally, this model shows how governmental policies that try to motivate firms to hire more people by increasing Ho can have exactly the opposite effect (of course, if firms fix $H^* = Ho$, the local correlation between them will be positive).[18]

$$\frac{dH}{dFC} = - \frac{N.(HJ'+J)}{C.(J''.H+2J')} > 0 \qquad (2.13a)$$

$$\frac{dH}{dHo} = \frac{N.Wo.b.(HJ'+J)}{C.(J''.H+2J')} < 0, \qquad (2.13b)$$

[17] We should remark that this is a very degenerate case. If the normal hours of work per person could be divisible, the effects of increases in Wo would be a diminution of H because the increase in the relative marginal cost of hours of work. Variations of Ho would not have any impact if H continues to be smaller than Ho.

[18] This point was noticed before by Ehrenberg (1971) and Bell (1982).

Figure 2.5 (a)

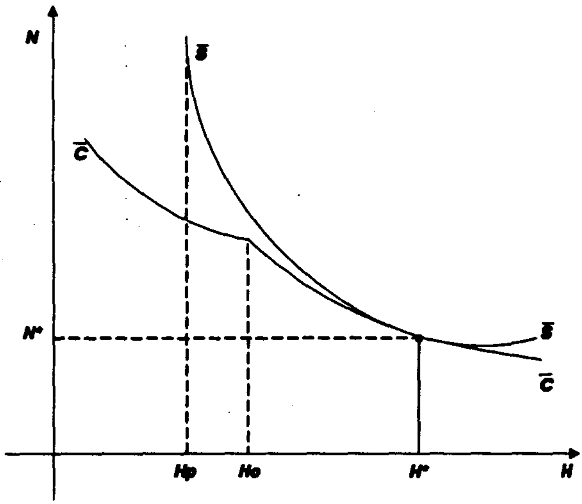
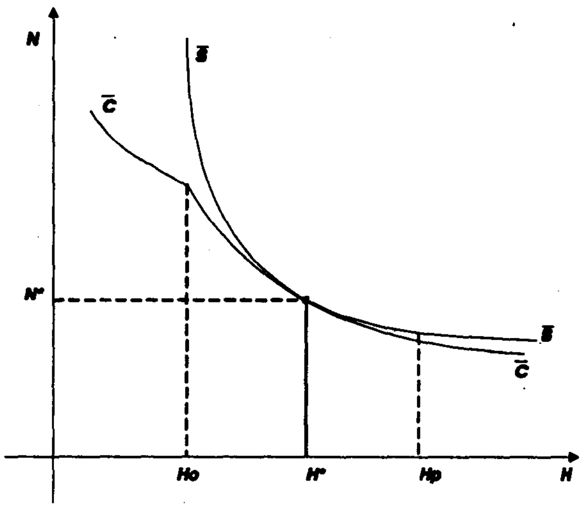


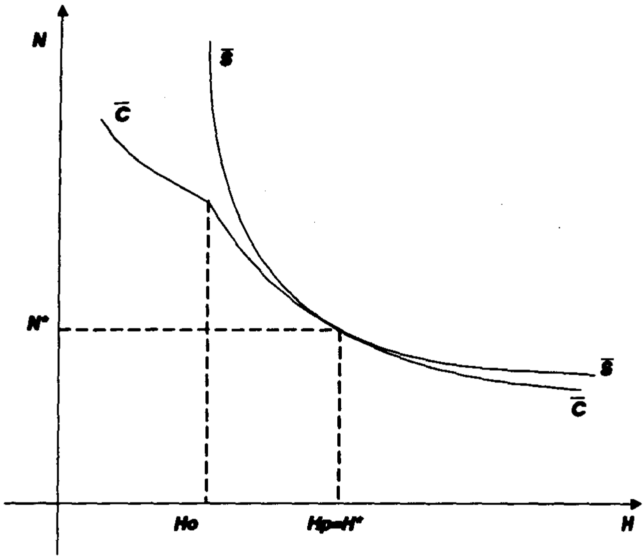
Figure 2.5 (b)



$$\frac{dH}{dWo} = -\frac{N.\{H^2.J'.(1+b) - b.Ho.(J'H+J)\}}{C.(J''.H+2J')} < 0 \quad (2.13c)$$

$$\frac{dH}{db} = -\frac{N.\{H^2.J'.Wo - Wo.Ho.(J'H+J)\}}{C.(J''.H+2J')} < 0 \quad (2.13d)$$

Figure 2.5 (c)



The effect of Pc on H will depend on the portion of the production function in which the firm is working, *i.e.*, on the sign of $J'(.)$, as we can see in (2.13 e),

$$\frac{dH}{dPc} = - \frac{N.\,J'\,.\,H^2}{C.(J''.H+2J')} \gtreqless 0\,,\ \text{if}\ \varepsilon_{S,H} \gtreqless 1 \qquad (2.13e)$$

Therefore, if we do not know the relevant region of the production function for a representative firm, it can be determined by using the sensitivity of employment and hours of work per person to variations in Pc.

One last important point is that the optimal level of work hours determined by this firm is independent of the output level. In equations (2.11), (2.12) and (2.13), the optimal level of H does not depend on the level of output. This result depends crucially on the proportional relation assumed between: a) labor services and employment level; and b) capital services and total labor hours. This is not a bad characteristic of our model since these assumptions are reasonable and, in fact, labor hours (H) tend to be very stable through time.

$$N^* = F^{-1}(\bar{X}) \cdot (J(H^*) \cdot H^*)^{-1} \qquad (2.14)$$

So, we can say that, first, the firm determines H^* given the cost variables and the labor services function. After that, it determines the number of

employees given the level of output[19] as described in equation (2.14). The fact that H^* is independent of the output level is crucial for the specification of the empirical equation in the next section.

3. Labor adjustment costs and the equation to be estimated[20]

The introduction of uncertainty in the preceding model makes relevant the interpretation of labor as a quasi-fixed factor of production.[21] In other words, aside from the fixed costs per employee, *FC*, that are relevant even in the long-run, the firm incurs in on-the-job training and instruction per employee costs. Therefore, when the output varies in the short-run, our representative firm will not adjust immediately the number of workers according to its long-run cost minimization level. After a while, when the firm is able to distinguish the permanent from the temporary component of this output variation, it adjusts N to N^*.

In figure 3.1 (a) and (b), we show the dynamic of adjustment for N, H and L when the output level varies. We assumed that $H^* = H_P$, since the optimal value of H depends on the parameters of our problem. This is just one "possible" equilibrium configuration for H and it is used here for the purposes of exposition. If, for instance, the output level increases from $\bar{X}$ to $2\bar{X}$, H will increase to H_{max}; N will increase to N_1; and the total labor hours, L, will increase to $\bar{L}$. The ratio N/H can increase or decrease initially, but along the adjustment path, the firm will perceive the permanent characteristic of the output variation and this ratio will increase until it reaches N_1^*/H^*. Given our assumption that $H^* = H_P$, L will decrease along the adjustment path to $\bar{L}_{min}$. This is an important point: *for a given level of output, the total labor hours varies along the adjustment path.* When output diminishes the adjustment path is symmetric and is described in figure 3.1 (b).

This kind of continuous pattern of adjustment assumes that the adjustment costs of the labor force are a convex function of movements in the employment level. We will not discuss the validity of this assumption. Holt et alii (1960)

[19] Of course, if the firms were profit maximizers, instead of just cost minimizers, in this "second stage" they would fix the level of output. We will not build a profit maximization version of this model since we will assume in the empirical part of this paper that the industrial sectors take the output level as given.

[20] We will not introduce formally uncertainty or labor adjustment costs in our model since this is beyond the scope of the paper. Furthermore, the consequences of this uncertainty seem to be straightforward and are presented intuitively in this section.

[21] See Becker (1962), Mincer (1962) and Oi (1961).

Figure 3.1 (a)

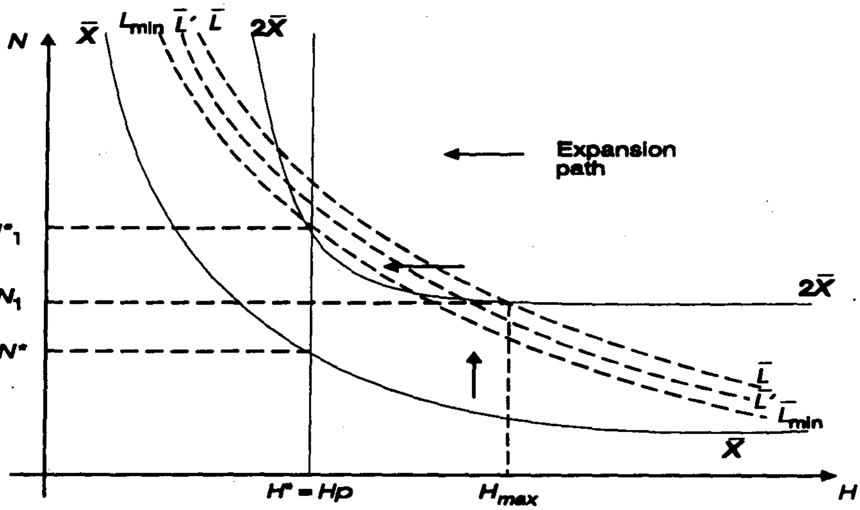
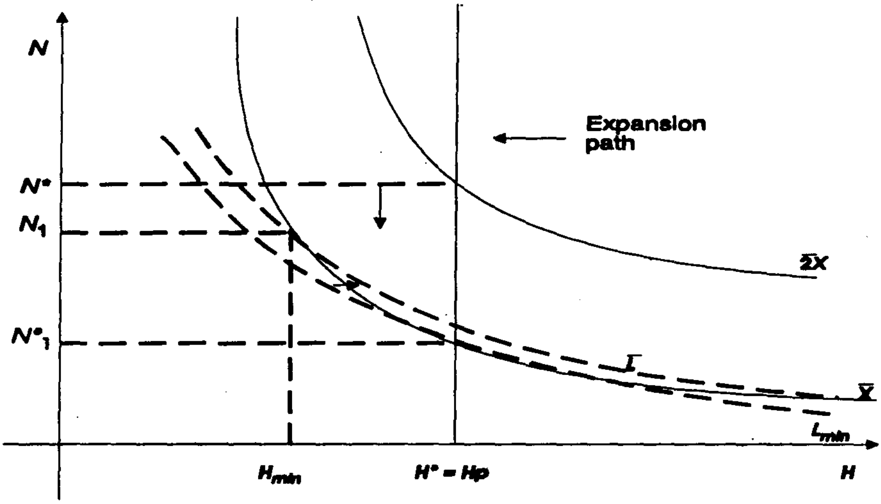


Figure 3.1 (b)



were the first to work with this hypothesis and the justification for it was summarized by themselves:

"Whether these costs actually rise at an increasing or decreasing rate is difficult to determine. It can be argued that reorganization costs are more than proportionately larger for larger layoffs than for small layoffs; and similarly the efficiency of hiring, measured in terms of the quality of the employees hired, may fall when a large number of people are hired at one time. If this argument

holds, then the quadratic curve still can give a tolerable approximation over a range."

Hamermesh (1988) tried another specification for the adjustment equation and showed that if this convexity hypothesis is not true, then the dynamics of adjustment are completely different. He found empirically that the assumption of fixed costs of adjustment is better at the plant level; but that when the level of aggregation increases, the convex costs specification becomes more powerful in explaining the data. Since we will work at a high level of aggregation in the empirical part of this paper, our assumption of convex adjustment costs of the labor force seems reasonable.

Now we are ready to specify an equation that captures the two basic features of the relationship between employees and hours of work per person: a) the substitutability between them when the cost variables change; and b) the role of H as a short-run adjustment variable when output varies.

The first problem is the simultaneity between N and H, *i.e.*, for given levels of output and cost variables and depending on the adjustment timing, the firm will fix N and H simultaneously. Various authors missed this very basic point and tried to build a one-equation model using a partial adjustment specification for the level of employment with output.[22] This approach generates inconsistent estimates of the parameters, since the variable "hours of work per person" will be included in the regression error and then will be correlated with the output level. In Hart & Sharot (1978), the authors build a recursive model that tries to deal with this simultaneity problem, but they had to make very strong assumptions. Moreover, recursiveness does not, fundamentally, correct simultaneity problems.

We will not propose a simultaneous equation model here, either. In order to deal with the simultaneity between N and H, we will study behavior of the ratio $\frac{N}{H}$. In this way, we normalize variations in the level of employment so that labor hours will not be included anymore in the regression error. Furthermore, the model we built before permits a straightforward interpretation of this ratio in both the long-run and the short-run. Our basic equation is:[23]

[22] See, for instance, Ball & St. Cyr (1966), Brechling (1965) and Ireland & Smith (1970). For works about the Brazilian industry see Bugarin (1989), Calabi & Luque (1985), Camargo & Landau (1985), Chahad & Luque (1986, 1989) and Meller (1980). In Pereira et alii (1985) the authors develop a long-run approach for the employment absorption of the Brazilian industry that by definition does not deal with short-run movements of employment and labor hours.

[23] Notice that this specification assumes that the process of adjustment is continuous. As Rosen (1968) suggested, we will focus on the ratio of employment to hours of work per person.

$$\text{Log}\left[\frac{N}{H}\right]_t = k + a_0 \cdot x_t + a_1 \cdot x_{t-1} + a_2 \cdot x_{t-2} + \ldots + \sum_{j=1}^{s} dj \cdot vcj_t + u_t \qquad (3.1)$$

k = constant;

x = Log (X);

vcj_t = Log (jth cost variable).

Additionally we can say that u_t is white noise if all the cost variables are included in the equation to be estimated. Or we can introduce the lag operator:

$$\text{Log}\left[\frac{N}{H}\right]_t = k + a_0 \cdot x_t + a_1 \cdot L \,.\, x_t + a_2 \cdot L^2 \cdot x_t + \ldots + dj \cdot vcj_t + u_t =$$

$$= k + A\,(L) \cdot x_t + dj \cdot vcj_t + u_t \qquad (3.1a)$$

Here each parameter a_j measures the impact on the ratio between N and H "j" periods ahead of variations in output "today". Since H is fixed in the long-run (for given cost variables and technology), the infinite sum of these coefficients is positive and, in general, we should expect a positive sign for each of them. This is not necessarily true for the coefficients of more recent lags of output. They can be negative if variations in output cause bigger changes in H than in N in the very short-run.

The dynamics of employment and hours of work per person in the short-run depend on the amount of investment made by firms in their labor force. So, for identical variations in output, changes in the employment level of high investment labor categories should lag changes in the employment level of low investment categories. Symmetrically, changes in hours of work per person should lead them. Therefore, we should expect low values, that slowly converge toward zero, for the a_is of high investment labor categories when compared to low level categories.

But, in order to make possible the estimation of (3.1) we have to impose restrictions on the coefficients of the output lags. Following Jorgenson (1966), we will approximate the lag structure for the a_is by the ratio of two polynomials, $A(s) = \frac{F(s)}{E(s)}$. Since we want to minimize the number of parameters to be estimated we can write the two polynomials $F(\cdot)$ and $E(\cdot)$, after some normalizations, as: $F(L) = a_0 + a_1 \cdot L$, and, $E(L) = 1 - c \cdot L$. By substituting this expression in (3.1a), multiplying both sides by $[1 - c \cdot L]$ and rewriting the final expression, we get an equation ready to be estimated:

$$\text{Log}\left[\frac{N}{H}\right]_t = k' + a_0 \cdot x_t + a_1 \cdot x_{t-1} + c \cdot \text{Log}\left[\frac{N}{H}\right]_{t-1} + dj \cdot cvj_t^{*} + v_t \qquad (3.2)$$

where:

$$k' = k \cdot (1 - c)$$

$$cvj_t^{*} = cvj_t - c \cdot cvj_{t-1}$$

$$v_t = u_t - c \cdot u_{t-1}$$

We need the assumption, to be tested, that $|c| < 1$ in order to the sum of the a_is to be a finite number. If this condition does not hold, then the dependent variable will follow an explosive pattern of adjustment when output varies.

3.1 The data specification

In the next section, we will show estimates for (3.2) based on Brazil's and on São Paulo's industry sectors data. The basic reason for this option is to have different estimates of the same basic equation. In this sense, we do not intend to make an intensive study of a specific sector. We will just try the above specification to detect the existence of employment adjustment costs and substitutability between workers and hours of work per person. The comparison between the data at the national level and the data at the São Paulo state level is used as a control device for the degree of employment rigidity in face of variations in output. Since the most modern and advanced industries in Brazil are located in São Paulo, we expect that the estimated coefficients for the output lags in the sectors of São Paulo's industry reflect the existence of higher employment adjustment costs when compared with the estimates of the same industries at the national level.

The main problem of this direct comparison approach is that the long-run output-employment elasticities may be different in the two different levels of aggregation. For instance, a higher output-employment elasticity can be confused with a smaller adjustment cost of the labor force. In other words, the a_is can always be bigger in this case than in a situation wherein the output-employment elasticity is smaller.

We will deal with this problem looking at the proportion between the partial sum of the coefficients of the output lags and their total sum. By doing this, we normalize the difference in these elasticities and focus our attention on the timing of adjustment of labor hours and employment in each sector. For output

data of each sector, we will use the PIM-PF/IBGE [24] for both Brazil and the state of São Paulo.

Some authors argue that the level of output should not be used for comparisons among different categories of workers. This argument is based on the fact that "output" is not an homogeneous concept and thus we should use different measures of output to analyze the behavior of employment and hours of work per person in each category. One solution for homogenizing the relevant output for each labor category would be to use the total hours of labor as a proxy for the level of output.[25]

This solution is not appropriate. As already showed, even if the level of output is taken as given by the firm, the number of total labor hours hired will vary when the ratio between N and H changes during the adjustment toward the long-run equilibrium point (as we saw in figure 3.1). Thus, if we substitute total hours of work for the output level in equation (3.2), we will not be able to interpret the sum of the coefficients of the output lags as the long-run sensitivity of employment to changes in output. Furthermore, it would be wrong to assume that the total hours of labor is exogenous, since it changes when the proportion of employment and hours of work per person varies.

Since we will not analyze the behavior of employment among different categories of work within one sector, but the behavior of aggregate employment between sectors, we believe that the output of each sector can be maintained as an explanatory variable. Therefore, we again avoid a simultaneity problem between a regressor and the left-hand side variable.

We will introduce two cost variables in equation (3.2): w = the logarithm of the marginal cost of one hour of work; and pc = the logarithm of real cost of fuel and lubricants. Therefore the equation to be estimated is:

$$\text{Log}\left[\frac{N}{H}\right]_t = k' + a_o \cdot x_t + a_1 \cdot x_{t-1} + c \cdot \text{Log}\left[\frac{N}{H}\right]_{t-1} +$$

$$+ d_1 \cdot w_t + d'_1 \cdot w_{t-1} + d_2 \cdot pc_t + d'_2 \cdot pc'_{t-1} + v_t \qquad (3.3)$$

where the lower case letters represent the logarithms of the respective variables.[26]

[24] *Monthly Industrial Report* - Production/Brazilian Institute of Geography and Statistics.

[25] See Rosen (1968), Fair (1969) and Craine (1973).

[26] Notice that this methodology imposes a non-linear restriction on some parameters. In the next section we will test them as a way to evaluate the specification and the transformations made until now.

It is not possible to find disaggregated cost data for each spending category, such as normal hourly wage rate, premium rate paid for each extra-hour worked, expenses for a day-care center, etc. At the national level, the best data base is the *New Monthly Industrial Report – General Data*/IBGE (PIM-DG/IBGE). We divided the data series "value of total extra-hours paid" by "total paid hours direct related to the production process" and the corresponding wholesale price index calculated by Fundação Getulio Vargas (FGV-RJ). We used the data base provided by the Federation of the Industries of São Paulo for the state level data. Then we calculated W dividing the index "total nominal wages" by "hours worked in the production process" and the corresponding regional wholesale price index calculated by FGV-RJ.

So our hourly cost data is:

$$\text{Brazil - IBGE: } W = \frac{Wo \,.\, (1+b) \,.\, (H - Ho) \,.\, N}{H \,.\, N \,.\, P}$$

$$\text{São Paulo - FIESP: } W = \frac{Wo \,.\, Ho \,.\, N + Wo \,.\, (1+b) \,.\, (H - Ho) \,.\, N}{H \,.\, N \,.\, P}$$

One could argue that the inclusion of H in our data could cause a spurious relationship between the right hand side variable w and the dependent variable Log (N/H) in equation (3.3). But if we differentiate the expressions for W above with respect to H, we will see that W varies positively with H. So if H increases, due to any exogenous factor, w will increase and the dependent variable will decrease. This causes a spurious negative relationship between hourly labor cost and the ratio of employment to hours of work per person. Since we should expect this relationship to be positive, we have a stronger reason to believe in the relevance of the substitution between employment and hours of work per person when the coefficient of this cost variable is positive and significant in equation (3.3).

It is very difficult to build an index for the relevant non-labor inputs in each industrial sector. Thus we included the "real wholesale price of fuel and lubricants" (Pc) in (3.3). This data is in the form of a ratio between the "wholesale price of fuel and lubricants" and the "wholesale price" of each sector.[27] This index is a good proxy for the real price of inputs in each sector, and has been included in our equation so as we could have an estimate of the production function segment relevant for each sector.

So, if the coefficient of this variable is positive, the sector works in a region where $H^* > Hp$ (the level of work hours where the productivity of a stock of workers achieves its maximum). In other words, if the operation cost of the

[27] These data were calculated by FGV-RJ.

capital stock increases, the firms will want to reduce the total labor hours hired, since the utilization of the capital stock is positively related to this variable. If the firms increase the level of employment and diminish the number of hours each employee works, in order to decrease the total labor hours hired, then they are producing in the region of the labor services function where the marginal productivity of labor hours is negative. If the sign of the coefficient is negative, then the firms work in the region where $H^* < Hp$. When this coefficient is zero, $H^* = Hp$.

Although this is an imperfect and very indirect method for estimating the sensitivity of output to changes in the hours of work per person in a given level of employment, we consider is better than the "direct approach" generally used in the literature.[28] In this approach, the authors invert a production function with employment and work hours as separate variables, and regress employment on output and hours of work per person. This methodology generates inconsistent estimates of the parameters, since it does not include cost variables in the equation needed to deal with the substitutability between labor hours and employment. Furthermore, the variable for hours of work per person will be correlated with the regression error, because it is determined simultaneously with employment in the firm's cost minimization process.

3.2 The estimation procedure

The estimation method to be used will depend on the assumption we make about the random process that governs the path of the errors in the structural equation (3.1). As noted above, if all cost variables were included in the right-hand side of (3.1), we could say that u_t follows a white noise process. In this case, the regression error in equation (3.3) follows a *MA* (1) process or, equivalently, since $|c| < 1$, it follows an *AR* (∞) process. Then, the estimation of (3.3), using *OLS*, generates inconsistent estimates, because there is a lag of the dependent variable in its right-hand side and, consequently, it will be correlated with the error.

However, we cannot be sure that all the relevant cost variables are represented by w and pc. For instance, the labor costs not related to the number of hours of work per person (*FC*) may change significantly through time [29] and

[28] See, for instance, Leslie & White (1980) and Craine (1973).

[29] Since this data is not available, we had to assume that it is approximately constant through time and, then, changes in w are good proxies for variations in the marginal costs of hours of work per person relatively to the employment level. In fact, it seems reasonable that this variable does not change so much or at least follows a trend equal to the very long-run tendency of the employment level. It may present large variations when the labor legislation changes, as it happened in 1989 with the new constitution. We tried to introduced a dummy variable for this period but it was not relevant in any sector.

we should expect some correlation among the lags of this variable. This would cause serial correlation in the errors of (3.1); hence the errors of (3.3) could follow any random process. We will assume that, for any random process followed by v_t we can always transform it in an *AR* (∞). Under the very common assumption of stationariness of u_t and $|c| < 1$, we can always transform the general *ARMA* (.,.) process that governs v_t into an *AR* (∞). In some cases, the final form for the random process of v_t will even present a declining pattern for the lag of the coefficients of the regression errors.[30]

Since it seems inappropriate to make an ex ante assumption about the random structure of the regression errors, and given our discussion in the past subsection, we propose the following method of estimation:

1) Estimate equation (3.3) for each sector of São Paulo and of Brazilian industry using *OLS*.

2) Make the test for the existence of autocorrelation proposed by Godfrey (1978 a and b) and Breusch (1978). We will test the existence of autocorrelation up to the 12th order[31] using the Lagrange multiplier version of this test for *AR*(r) that: (a) uses the residuals of the *OLS* regression in the first step and regresses them on the explanatory variables and on the lags of order 1,2,..., r, of the residuals; (b) builds the statistic nR^2, where n is the number of observations and the R-square is the one obtained in this last regression; and (c) under the null hypothesis of non-autocorrelation, this statistic has a Chi-square distribution with r degrees of freedom.

3) If the residuals do not present serial correlation,[32] we will use the estimates obtained in the first step in the rest of the paper. If the residuals present serial correlation of any order, the estimates obtained in the first step will be inconsistent since there is a lag of the dependent variable in the right-had side of (3.3) and this will be correlated with the regression error. We will use a Maximum Likelihood approach with the Gauss-Newton iterative method.

More specifically, let us assume that the disturbance, v_t, follows the *AR*(r) process

[30] If, for instance v_t follows an *ARMA* (1,1) with parameters ρ and c, where $|c|$ and $|\rho| < 1$ by hypothesis, the coefficients of the lags of v_t will decline geometrically. This case corresponds to a situation where the original error, u_t, follows an *AR* (1) with parameter ρ significantly different from c.

[31] The basic reason for this limit is computational cost and we are implicitly assuming that the relevant *AR* process can be approximated by *AR* process of order 12 or of smaller order.

[32] This is not very likely since in this case the residual of the structural equation have to follow an *AR*(1) with ρ very close to c.

$$v_t = \sum_{i=1}^{r} \rho_i \cdot v_{t-1} + \varepsilon_t \ , \quad \varepsilon_t \sim N(0, \sigma_\varepsilon^2)$$

with "fixed initial" values. The fixed initial value assumption is the same as treating the first r observations of the dependent variable as given and non-stochastic.[33] The log-likelihood function for this case is defined by:

$$LL(\phi) = -\frac{n-r}{2} \log(2\pi\sigma_\varepsilon^2) - \frac{1}{2\sigma_\varepsilon^2} \sum_{t=r+1}^{n} \varepsilon_t^2 + C \tag{3.4}$$

where $\phi = (\beta', \sigma_\varepsilon^2, \rho')$, with β = vector of the coefficients of (3.3) and $\rho = (\rho_1,...,\rho_r)'$. Notice that the constant term C in (3.4) is undefined, and that it is usually made equal to zero. The method we will use maximizes (3.4), or, equivalently, minimizes $\sum_{t=r+1}^{n} \varepsilon_t^2$ with respect to ϕ by the Gauss-Newton iterative method.

The computations for the Gauss-Newton procedure are based on the following iterative relations:[34]

$$\begin{bmatrix} \tilde{\beta} \\ \tilde{\rho} \end{bmatrix}_j = \begin{bmatrix} \tilde{\beta} \\ \tilde{\rho} \end{bmatrix}_{j-1} + \begin{bmatrix} \tilde{X}'_* \ \tilde{X}'_* & \tilde{X}_*' S \\ S' \ \tilde{X}_* & S' S \end{bmatrix}_{j-1}^{-1} \begin{bmatrix} \tilde{X}'_* \tilde{\varepsilon} \\ S' \ \tilde{\varepsilon} \end{bmatrix}_{j-1}$$

where the sub-scripts j and j-1 here refer to the j-th and the (j-1)-th iterations; and:

$\tilde{\varepsilon} = (\tilde{\varepsilon}_{r+1}, \tilde{\varepsilon}_{r+2}, \ldots, \tilde{\varepsilon}_t)'$ with $\tilde{\varepsilon}_t = \tilde{v}_t - \sum_{i=1}^{r} \tilde{\rho}_i \tilde{v}_{t-i}$, $t = r+1, \ldots, n$;

$\tilde{X}_* = X - \sum_{i=1}^{r} \tilde{\rho}_i X(-i)$, where X is the $(n\text{-}r)xk$ matrix of regressors in (3.3);

[33] See Judge et alii (1985).

[34] The symbol ~ stands for ML estimators.

S is an $(n\text{-}r)xr$ matrix containing the r lagged values of the "Gauss-Newton" residuals, $\tilde{v}_t = y_t - \sum_{i=1}^{k} x_{it}\tilde{\beta}_i$, $t = 1, 2, \ldots, n$. So,

$$S = \begin{bmatrix} \tilde{v}_r & \tilde{v}_{r-1} \ldots & \tilde{v}_1 \\ \tilde{v}_{r+1} & \tilde{v}_r \ \ldots & \tilde{v}_2 \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \tilde{v}_{n-1} & \tilde{v}_{n-2} \cdots & \tilde{v}_{n-r} \end{bmatrix}$$

We start the iterations with:
$\tilde{\beta}_{(0)} = \tilde{\beta}_{OLS} = (X'X)^{-1}X'y$,
$\tilde{\rho}_{(0)} = 0$

and end them if: $\sum_{i=1} \left| \tilde{\rho}_{i,(j)} - \tilde{\rho}_{i,(j-1)} \right| < \frac{r}{1000}$

where $\tilde{\rho}_{(j)} = (\tilde{\rho}_{1,(j)}, \tilde{\rho}_{2,(j)}, \ldots, \tilde{\rho}_{r,(j)})'$, and $\tilde{\rho}_{(j-1)}$ stand for estimators of ρ in the j-th. and $(j\text{-}1)$th. iterations respectively.

The estimator of σ_ε^2 is computed as:

$$\hat{\sigma}_\varepsilon^2 = \sum_{t=r+1}^{n} \tilde{\varepsilon}_t^2 / (n - 2r - k)$$

and the estimator of the asymptotic variance matrix of $\tilde{\phi} = (\tilde{\beta}, \tilde{\rho})$ is computed as

$$\hat{V}(\phi) = \hat{\sigma}_\varepsilon^2 \begin{bmatrix} \tilde{X}'_* \tilde{X}_* & \Big|\Big| \tilde{X}'_* \ S \\ S' \ \tilde{X}'_* & S' \ S \end{bmatrix}^{-1}$$

4) We analyze the results obtained in step 3 (or 1, in the no autocorrelation case). In particular, we calculate the coefficients for the output lags and see if they follow a pattern that matches the hypothesis that the labor adjustment costs are significant. After that, we will calculate the proportion of the total adjustment at the end of one year, $\left[(\sum_{i=0}^{11} a_i) \ / \ (\sum_{i=0}^{\infty} a_i) \right]$ and the number of months

required in each sector for 90% of the adjustment in the labor force to be completed. We expect that the labor adjustment process at the national level is faster than in São Paulo state.

5) In this last step, we will carry out a test to check if the non-linear restrictions on the parameters of (3.3) are obeyed. Therefore, the null hypotheses are:

$$H_0 : d_1 c = -d_1' \text{ or } f_1(\beta) = ((d_1 c)/d_1') = -1 \text{ and}$$

$$H_0 : d_2 c = -d_2' \text{ or } f_2(\beta) = ((d_2 c)/d_2') = -1$$

The test statistic is $z_i = \dfrac{f_i(\hat{\beta}) + 1}{est.std.error}$, $i = 1, 2$. The estimated standard error for $f_i(\hat{\beta})$ can be constructed using a linear Taylor series approximation of $f_i(\hat{\beta})$ around the true value for the parameters. As a final result we have:

$$\text{estimated std. error } i \simeq \hat{g}_i' \text{ Var } [\hat{\beta} - \beta] \, \hat{g}_i , \; \hat{g}_i = \frac{\partial f_i(\hat{\beta})}{\partial \beta}$$

Then, under the null hypothesis, z_i will be distributed as a t-Student random variable. Since we are not very confident about the role played by the real cost of fuel in equation (3.3), we will consider the rejection of the restriction on the coefficient of w_{t-1} as a more serious sign that our approach for this specific sector is inadequate.

4. The empirical results[35]

In tables 1 and 2, we show the first round of estimation for the industrial sectors at the national level and at the São Paulo state level, respectively. We could not include all sectors of industry since we were using different data bases and, when we put them together, not all data series were available for all sectors.

The period of estimation for the national level of aggregation is Jan.1985 to Dec. 1989, since this data base began to be calculated in 1985. For São Paulo, we are using data from Jan. 1975 to Dec. 1989. The estimates for the five-year

[35] The tables are listed in the Appendix.

period used at the national level generated the same general results as the ones obtained in the fifteen-year time period reported in the tables. So, we kept the larger sample in order to have larger degrees of freedom. Data for Jan. 1990 to Dec. 1991 were not available at the time this research was completed.

In these tables, we reported, additionally, a Lagrange Multiplier version of a statistic test for heteroscedasticity. This test is based on the auxiliary regression $\hat{\varepsilon}_t^2 = \text{const.} + \alpha \hat{y}_t^2$, where $\hat{\varepsilon}_t$ = residuals of the regression; $\hat{y}_t$ = fitted values of the dependent variable. The null hypothesis is α=0 and the test statistic has a Chi-square distribution with one degree of freedom. We made some other specifications for the format of heteroscedasticity but they did not reject the null hypothesis for any sector. Even in the test for the specification shown above, the homoscedasticity hypothesis is rejected only in the "Electrical Equipment" sector at the national level. In this case, we used the Adjusted White's Heteroscedasticity-consistent estimates of the standard deviations of the parameters to calculate the t-statistics.[36]

We did this test because we believed that the capacity of a firm to adjust the number of hired employees would vary with the level of employment itself. That is, for higher levels of employment within a firm, its ability to internally reallocate personnel would also be higher. Thus, the sensitivity of the employment level during the business cycle would be smaller. The test rejects this hypothesis as a common characteristic of the industrial sectors.

In general, the test for autocorrelation indicates the existence of serial correlation of 12th order as we expected. Unexpectedly, however, for five sectors of industry at the national level (Non-metal Products, Machinery, Electrical and Communication Equipment, Paper Products and Plastic Products) we did not detect the existence of autocorrelation of any order. In tables 1 and 2 we reported just the statistic for the 12th order test. Therefore, in these cases the errors in the structural equation follows an $AR(1)$ with correlation coefficient, ρ, not significantly different from c.

In tables 3 and 4 we show the final estimates to be analyzed. For the five sectors in which we did not detect the existence of serial correlation of any order, we repeated the results shown in table 1. For all of the other sectors, we estimated equation (3.3) using the Maximum Likelihood method described above, assuming $r = 12$.

The signs of all relevant coefficients are those which our theory predicts. The coefficient of the hourly cost of labor is positive and is significantly different from zero at the 5% significance level in all sectors for both levels of aggregation. This coefficient is significantly different from zero at the 1%

[36] We used the degree of freedom corrected version of White's (1980) estimator. For a discussion about this correction see Mackinnon and White (1985).

significance level for all sectors at the state level and for the majority of the sectors at the national level.

Under the assumption of our model and the condition that *pc* is a good proxy for the real cost of the intermediary goods, the estimates for the coefficient of *pc* indicate that a majority of the industrial sectors operates at the point where the optimal number of hours of work per person maximizes the marginal productivity of their employees ($H^* = Hp$). These are the sectors where the coefficient of *pc* is zero. In these cases, the elasticity of labor services with respect to hours of work per person is 1 and is equal to the elasticity of labor services with respect to employment. For the sectors where we estimate a negative coefficient for *pc*, this elasticity is greater than one and greater than the elasticity of labor services with respect to employment, meaning that $H^* \leq Hp$. Therefore, in general, marginal increases in H, for a given level of employment, tend to affect the output level more than marginal increases in N, for a given level of H.

Table 5 shows the implicit values for the coefficients of the output lags. The structure of these coefficients illustrates the unequivocal existence of labor adjustment costs in Brazilian industry. The changes in the number of hours of work per person in the first month following an output variation are greater than the variation in the employment level. After that, the employment level continues its path toward its long-run level and the number of hours of work per person moves back to its long-run level.

Tables 6 and 7 show that, in general, the adjustment of the labor force is faster at the national level than at the São Paulo state level, as expected. But there are two exceptions: the Textiles and the Transport Equipments sectors. Since we did not make a sectoral analysis in this paper, this finding should be studied more carefully in case studies of these specific sectors to determine why this is so.

Finally, the restrictions imposed on the cost parameters seem to be obeyed, in general. This means that the approach we used to build equation (3.3) is appropriate. In only two sectors the restrictions are strongly rejected (Machinery and Paper Products, at the state of São Paulo level). So, in future work, the specification of the equation to be estimated for these two sectors should be improved.

5. Final observations

We did not try, in this paper, to conduct an exhaustive study of the behavior of employment and hours of work per person in each sector of the Brazilian industry.Our motivation was different. We built a model which would give us some insight into the way firms fix employment and hours of work per person and into the sensitivity of these variables to cost and output changes.

We use the sectoral data for Brazilian industry to illustrate how our theoretical arguments could be used to explain some empirical regularities. However, this macroeconomic approach does not deal with some exceptions to these empirical regularities. At the least, it calls for more research, at the microeconomic level, of the two sectors that presented a slower adjustment process for the labor force at the national level than at the São Paulo state level, contradicting our previous expectations.

The strongest feature of our approach is to fix attention to the ratio of employment to hours of work per person in the empirical part which, thus, avoids the simultaneity problem between these variables. Furthermore, the results could be interpreted in a straightforward way, given the theoretical results derived earlier. The use of the data of hours of work per person is relatively new when compared to the previous works about labor demand in Brazilian industry and the approach we used should be further developed.

The weakest part of our work is the gap between the formalization of firm behavior in the long-run and its behavior in the short-run. This weakness did not allow us to formally derive the equation to be estimated and, so, we had to deal with and *ad hoc* specification. Remedying this can be the next step in the development of a second version of the approach presented in this paper.

Resumo

Este trabalho apresenta um modelo microeconômico de determinação do nível de emprego e horas de trabalho a longo prazo. Utiliza-se o modelo para especificar uma equação a curto prazo para o coeficiente emprego/horas de trabalho por pessoa, visando a identificar a existência do custo de ajuste da mão-de-obra na indústria brasileira. Buscamos também averiguar a substitutibilidade entre horas de trabalho por pessoa e emprego. Utilizamos a mesma equação em dois níveis de agregação (Brasil e estado de São Paulo) para diversos setores da indústria de transformação, a fim de aferir a especificação adotada. Constatamos que de modo geral a especificação atende bem aos objetivos; contudo, testes estatísticos mais elaborados revelaram que é preciso pesquisar mais para entender os resultados referentes a setores específicos.

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Appendix

Table 1
Brazil

Log (N/H) = k + a0.x + a1.x + c. Log (N/H) + d1.w + d1'.w + d2.pc + d2'.pc + u
(Feb. 1985 to Dec. 1989 - n = 59)

	k	a0	a1	c	d1	d1'	d2	d2'	R2	LM test for serial corr. Chi-S.(12)	LM test for heterosced. Chi-S.(1)	Estimation method
Manufacturing	0.951	-0.181	0.193	0.734	0.108	-0.043	-0.134	0.116	0.895	21.865	1.004*	OLSQ
	(2.95)	(-4.71)	(5.25)	(10.70)	(4.38)	(-1.47)*	(-2.95)	(2.50)				
Non-metal products	0.665	-0.206	0.352	0.702	0.054	-0.023	-0.101	0.082	0.943	10.927*	0.074*	OLSQ
	(2.86)	(-4.12)	(7.37)	(12.61)	(2.83)	(-1.12)*	(-3.01)	(2.44)				
Metal products	0.684	-0.256	0.377	0.726	0.051	-0.027	-0.054	0.031	0.882	24.473	0.002*	OLSQ
	(2.40)	(-4.33)	(7.30)	(10.25)	(2.58)	(-1.31)*	(-2.60)	(1.43)*				
Machinery	1.186	-0.123	0.163	0.664	0.071	-0.022	-0.105	0.093	0.682	13.364*	0.607*	OLSQ
	(2.96)	(-2.21)	(3.14)	(7.07)	(2.18)	(-0.60)*	(-1.68)	(1.53)*				
Elect. and comun. equip.	0.368	-0.101	0.131	0.921	0.048	-0.048	-0.059	0.023	0.866	15.680*	4.243	OLSQ
	(0.91)**	(-1.97)**	(2.72)**	(9.24)**	(1.60)**	(-1.97)**	(-1.03)**	(0.32)**				
Transport equipment	0.789	-0.146	0.178	0.810	0.076	-0.064	-0.101	0.075	0.857	25.020	0.062*	OLSQ
	(1.96)	(-4.61)	(5.83)	(12.48)	(3.32)	(-2.51)	(-2.13)	(1.52)*				
Paper products	0.355	-0.164	0.309	0.738	0.035	-0.000	-0.062	0.060	0.880	11.394*	1.438*	OLSQ
	(1.37)*	(-2.16)	(4.41)	(8.49)	(1.80)	(0.00)*	(-1.60)*	(1.60)*				
Plastic products	0.378	-0.086	0.195	0.779	0.093	-0.045	-0.172	0.153	0.898	18.631*	0.020*	OLSQ
	(1.38)*	(-1.12)*	(2.53)	(11.91)	(2.53)	(-1.16)*	(-2.48)	(2.14)				
Textiles	0.179	-0.215	0.346	0.844	0.075	-0.078	-0.101	0.091	0.914	28.122	0.454*	OLSQ
	(0.60)*	(-3.46)	(5.45)	(18.22)	(3.14)	(-3.16)	(-2.57)	(2.28)				

The numbers in parentheses are *t*-statistics.
* Non significant at 5% of significance.
** Adjusted white's heteroscedasticity-consistent estimates.

Table 2
São Paulo

$$\text{Log}(N/H) = k + a0.x + a1.x + c.\text{Log}(N/H) + d1.w + d1'.w + d2.pc + d2'.pc + u$$

(Feb. 1985 to Dec. 1989 - n =179)

	k	*a0*	*a1*	*c*	*d1*	*d1'*	*d2*	*d2'*	*R2*	*LM test for serial corr. Chi-S.(12)*	*LM test for heterosced. Chi-S.(1)*	*Estimation method*
Manufacturing	0.436	-0.348	0.381	0.872	0.071	-0.044	-0.015	-0.009	0.897	74.875	1.437*	OLSQ
	(3.51)	(-14.28)	(16.20)	(29.98)	(2.47)	(-1.49)*	(-0.50)*	(-0.29)*				
Non-metal products	0.324	-0.317	0.381	0.872	0.067	-0.040	-0.019	-0.011	0.927	41.162	0.000*	OLSQ
	(2.90)	(-8.36)	(10.65)	(27.85)	(2.80)	(-1.63)*	(-0.63)*	(-0.36)*				
Metal products	0.356	-0.322	0.373	0.856	0.039	-0.004	-0.005	-0.010	0.941	28.167	1.089*	OLSQ
	(3.79)	(-11.08)	(13.68)	(26.89)	(1.57)*	(-0.17)*	(-0.17)*	(-0.38)*				
Machinery	0.366	-0.257	0.294	0.906	0.237	-0.228	0.007	-0.038	0.941	50.709	0.859*	OLSQ
	(2.41)	(-8.29)	(9.62)	(29.14)	(6.73)	(-6.15)	(-0.16)*	(-0.86)*				
Elect. and comun. equip.	0.607	-0.381	0.387	0.884	0.146	-0.108	-0.028	-0.030	0.939	37.980	2.880*	OLSQ
	(2.54)	(-12.54)	(12.76)	(30.20)	(4.83)	(-3.46)	(-0.67)*	(-0.71)*				
Transport equipment	0.634	-0.322	0.361	0.715	0.239	-0.105	-0.055	0.031	0.853	34.143	0.059*	OLSQ
	(3.59)	(-14.09)	(16.23)	(17.58)	(7.60)	(-3.03)	(-1.25)*	(0.71)*				
Paper products	0.423	-0.336	0.386	0.842	0.017	-0.017	0.003	0.016	0.943	23.515	0.024*	OLSQ
	(3.71)	(-8.97)	(11.07)	(19.95)	(0.83)*	(-0.86)*	(0.11)*	(0.57)*				
Plastic products	0.376	-0.137	0.216	0.827	0.182	-0.149	-0.025	0.007	0.883	43.669	1.782*	OLSQ
	(2.67)	(-4.18)	(6.55)	(23.07)	(5.54)	(-4.60)	(-0.65)*	(-0.17)*				
Textiles	0.676	-0.186	0.241	0.776	0.075	-0.025	-0.069	0.046	0.840	45.711	0.088*	OLSQ
	(4.11)	(-6.91)	(9.21)	(18.72)	(3.34)	(-1.06)	(-2.13)	(1.38)*				

The numbers in parentheses are *t*-statistics.

***Non significant at 5% of significance.**

Table 3
Brazil

Log (*N/H*) = *k* + *a*0.*x* + *a*1.*x* + c. Log (*N/H*) + *d*1.*w* + *d*1'.*w* + *d*2.*pc* + *d*2'.*pc* + *u*
(Feb. 1985 to Dec. 1989 - *n* = 59)

	k	*a*0	*a*1	*c*	*d*1	*d*1'	*d*2	*d*2'	*R*2	*Estimation method*
Manufacturing	0.788	-0.199	0.221	0.779	0.122	-0.066	0.011	-0.042	0.938	M.L.
	(3.41)	(-7.00)	(8.04)	(15.47)	(4.86)	(-2.33)	(0.38)*	(-1.39)*		
Non-metal products	0.665	-0.206	0.352	0.702	0.054	-0.023	-0.101	0.082	0.943	OLSQ
	(2.86)	(-4.12)	(7.37)	(12.61)	(2.83)	(-1.12)*	(-3.01)	(2.44)		
Metal products	0.432	-0.131	0.211	0.816	0.025	0.009	-0.037	0.009	0.905	M.L.
	(2.45)	(-3.16)	(4.86)	(18.53)	(1.87)	(0.47)*	(-2.10)	(0.50)*		
Machinery	1.186	-0.123	0.163	0.664	0.071	-0.022	-0.105	0.093	0.682	OLSQ
	(2.96)	(-2.21)	(3.14)	(7.07)	(2.18)	(-0.60)*	(-1.68)	(1.53)*		
Elect. and comun. equip.	0.368	-0.101	0.131	0.921	0.480	-0.048	-0.059	0.023	0.866	OLSQ
	(1.04)*	(-2.21)	(2.81)	(11.82)	(1.70)	(-1.60)*	(-0.98)*	(0.38)*		
Transport equipment	0.214	-0.111	0.147	0.910	0.073	-0.052	0.014	-0.027	0.859	M.L.
	(1.93)	(-4.43)	(6.57)	(58.15)	(3.97)	(-2.67)	(0.48)*	(-0.91)*		
Paper products	0.355	-0.164	0.309	0.738	0.035	-0.000	-0.062	0.060	0.880	OLSQ
	(1.37)*	(-2.16)	(4.41)	(8.49)	(1.80)	(0.00)*	(-1.60)*	(1.60)*		
Plastic products	0.378	-0.086	0.195	0.779	0.093	-0.045	-0.172	0.153	0.898	OLSQ
	(1.38)*	(-1.12)*	(2.53)	(11.91)	(2.53)	(-1.16)*	(-2.48)	(2.14)		
Textiles	-0.256	-0.126	0.260	0.947	0.085	-0.090	-0.084	0.059	0.948	M.L.
	(-1.44)*	(-1.90)	(4.44)	(66.52)	(4.43)	(-4.46)	(-3.56)	(2.44)		

The numbers in parentheses are *t*-statistics.

* Non significant at 5% of significance.

Table 4
São Paulo

Log(*N/H*) = *k* + *a*0.*x* + *a*1.*x* + *c*.Log (*N/H*) + *d*1.*w* + *d*1'.*w* + *d*2.*pc* + *d*2'.*pc* + *u*
(Feb. 1975 to Dec. 1989 - *n* = 179)

	k	*a*0	*a*1	*c*	*d*1	*d*1'	*d*2	d2'	*R*2	*Estimation method*
Manufacturing	0.458	-0.318	0.389	0.835	0.085	-0.065	-0.015	-0.008	0.939	M.L.
	(3.73)	(-11.90)	(15.26)	(27.94)	(2.80)	(-2.15)	(-0.81)*	(-0.42)*		
Non-metal products	0.240	-0.165	0.239	0.870	0.055	-0.048	0.015	-0.018	0.944	M.L.
	(0.77)*	(-4.30)	(6.17)	(14.74)	(2.70)	(-2.39)	(0.56)*	(-0.72)*		
Metal products	0.247	-0.207	0.280	0.872	0.070	-0.051	0.001	-0.014	0.939	M.L.
	(5.21)	(-6.87)	(8.92)	(47.72)	(2.36)	(1.69)	(0.21)*	(-0.59)*		
Machinery	0.248	-0.103	0.172	0.911	0.262	-0.279	0.019	-0.039	0.966	M.L.
	(4.69)	(-3.75)	(5.84)	(68.48)	(7.43)	(-7.74)	(0.63)*	(-1.27)*		
Elect. and comun. equip.	0.068	-0.324	0.361	0.928	0.229	-0.183	-0.022	-0.001	0.953	M.L.
	(0.31)*	(-10.32)	(11.65)	(30.76)	(7.84)	(-5.97)	(-0.67)*	(-0.03)*		
Transport equipment	0.248	-0.298	0.340	0.825	0.245	-0.157	-0.062	0.052	0.884	M.L.
	(2.27)	(-14.64)	(17.19)	(27.52)	(6.91)	(-4.11)	(-1.58)*	(1.31)*		
Paper products	0.174	-0.127	0.149	0.938	0.108	-0.122	-0.026	0.043	0.949	M.L.
	(2.59)	(-2.73)	(3.28)	(32.30)	(4.36)	(-4.99)	(-1.07)*	(1.67)*		
Plastic products	0.163	-0.111	0.186	0.884	0.181	-0.170	-0.031	0.025	0.916	M.L.
	(1.00)*	(-3.24)	(5.32)	(24.11)	(6.21)	(-6.05)	(-0.94)*	(-0.73)*		
Textiles	0.531	-0.111	0.175	0.800	0.110	-0.070	-0.085	0.069	0.858	M.L.
	(2.15)	(-3.36)	(5.11)	(12.51)	(4.58)	(-2.60)	(-2.97)	(2.37)		

The numbers in parentheses are *t*-statistics.
*Non significant at 5% of significance.

Table 5
Coefficients for each output lag (Brazil)

	*a*0	*a*1'	*a*2	*a*3	*a*4	*a*5	*a*6	*a*7	*a*8	*a*9	*a*10	*a*11	*a*12
Manufacturing	-0.199	0.066	0.051	0.040	0.031	0.024	0.019	0.015	0.011	0.009	0.007	0.005	0.004
Non-metal products	-0.206	0.207	0.146	0.102	0.072	0.050	0.035	0.025	0.017	0.012	0.009	0.006	0.004
Metal products	-0.131	0.104	0.085	0.069	0.056	0.046	0.038	0.031	0.025	0.020	0.017	0.014	0.011
Machinery	-0.123	0.082	0.054	0.036	0.024	0.016	0.011	0.007	0.005	0.003	0.002	0.001	0.001
Elect. and comun. equip.	-0.101	0.038	0.035	0.032	0.030	0.027	0.025	0.023	0.021	0.020	0.018	0.017	0.015
Transport equipment	-0.111	0.046	0.042	0.038	0.035	0.032	0.029	0.026	0.024	0.022	0.020	0.018	0.016
Paper products	-0.164	0.188	0.139	0.103	0.076	0.056	0.041	0.030	0.022	0.017	0.012	0.009	0.007
Plastic products	-0.086	0.128	0.100	0.078	0.061	0.047	0.037	0.029	0.022	0.017	0.014	0.011	0.008
Textiles	-0.126	0140	0.133	0.126	0.119	0.113	0.107	0.101	0.096	0.091	0.086	0.082	0.077

Coefficients for each output lag (São Paulo)

	*a*0	*a*1'	*a*2	*a*3	*a*4	*a*5	*a*6	*a*7	*a*8	*a*9	*a*10	*a*11	*a*12
Manufaturing	-0.318	0.124	0.103	0.086	0.072	0.060	0.050	0.042	0.035	0.029	0.024	0.020	0.017
Non-metal products	-0.165	0.096	0.083	0.073	0.063	0.055	0.048	0.042	0.036	0.031	0.027	0.024	0.021
Metal products	-0.207	0.099	0.086	0.075	0.065	0.057	0.050	0.043	0.038	0.033	0.029	0.025	0.022
Machinery	-0.103	0.078	0.071	0.065	0.059	0.054	0.049	0.045	0.041	0.037	0.034	0.031	0.028
Elect. and comun. equip.	-0.324	0.060	0,056	0.052	0.048	0.045	0.042	0.039	0.036	0.033	0.031	0.029	0.026
Transport equipment	-0.298	0.094	0.077	0.064	0.053	0.043	0.036	0.030	0.024	0.020	0.017	0.014	0.011
Paper products	-0.127	0.030	0.028	0.027	0.025	0.023	0.022	0.021	0.019	0.018	0.017	0.016	0.015
Plastic products	-0.111	0.089	0.078	0.069	0.061	0.054	0.048	0.042	0.037	0.033	0.029	0.026	0.023
Textiles	-0.111	0.086	0.069	0.055	0.044	0.035	0.028	0.023	0.018	0.014	0.012	0.009	0.007

Table 6

Proportion of the total adjustment after 12 months of the variation in x

	São Paulo	Brazil
Manufacturing	0.799	0.851
Non-metal products	0.757	0.980
Metal products	0.737	0.887
Machinery	0.631	0.985
Elect. and comun. equip.	0.336	0.526
Transport equipment	0.775	0.589
Paper products	0.375	0.966
Plastic products	0.735	0.941
Textiles	0.908	0.452

Table 7

Number of months needed to complete 90% of the total adjustment

	São Paulo	Brazil
Manufacturing	15.9	13.5
Non-metal products	18.4	7.5
Metal products	19.0	12.6
Machinery	26.0	7.4
Elect. and comun. equip.	37.3	31.0
Transport equipment	16.2	27.0
Paper products	40.5	8.5
Plastic products	19.9	9.9
Textiles	11.6	43.4

Table 8

Tests of the non-linear restrictions on the coefficients

	Brazil (t-stat. (51))		São Paulo (t-stat. (168))	
	$b1^* c{=}b1'$	$b2^* c{=}b2'$	$b1^* c{=}b1'$	$b2^* c{=}b2'$
Manufacturing	-1.37	2.05*	-0.45	0.45
Non-metal products	-0.63	1.10	0.01	0.53
Metal products	0.51	-0.44	-0.82	0.68
Machinery	-0.41	1.19	9.69**	1.43
Elect. and comun. equip.	0.11	-0.27	-1.59	0.03
Transport equipment	-1.71*	1.09	-1.84*	0.08
Paper products	-0.00	0.85	2.89**	1.85*
Plastic products	-0.51	0.76	0.60	-0.16
Textiles	0.81	-1.78*	-0.85	0.09

* Reject the null hypothesis at 5% of significance.

** Reject the null hypothesis at 1% of significance.

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