Protection, Openness and Factor Adjustment: Evidence from the manufacturing sector in Uruguay

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Abstract

Using a panel of Uruguayan manufacturing firms we analyze the adjustment process in capital, blue collar and white collar employment. Adjustment functions are defined with respect to the gap between optimal and actual factor use. Our results confirm the asymmetric nature of factor adjustment, the relevance of nonlinearities and the interdependence between factor shortages. The average annual estimated desired to actual output gap due to adjustment costs for 1982-1995 was 2%. A clear relationship emerges between trade openness and adjustment functions of all three factors. Sectors experiencing stronger trade liberalization adjust less when creating jobs (reducing labor shortages) than sectors with lower changes in tariffs. Also, the larger (in absolute terms) the tariff reductions, the easier it became to adjust when destroying jobs (reducing labor surpluses). Overall the association of higher international exposure with factor adjustment is stronger for blue collar workers than for white collar workers. The results for capital are qualitatively similar but quantitatively smaller.

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1. Introduction

The traditional microeconomic textbook model assumes that the level of employment and capital used by firms is optimal at any point in time. However, since adjusting employment and capital is costly to firms, they often deviate from what would be optimal in the absence of frictions. [1]In this paper we analyze such adjustment process and how it may be affected by changes in trade policy.

There is a relatively large literature on adjustment costs in factor demand[2], however most of it focuses only in one factor of production. Those few studies that jointly consider the adjustment of capital and labor do not differentiate types of workers, and in general assume convex adjustment technologies and do not use firm level data. Hall (2004) is an example of this trend in the literature. He analyzes a long panel 1948-2001 at the two-digit level of aggregation for the US. Our approach uses firm level data, and allows each factor's adjustment to depend on the shortage of the other factors, hence allowing for some extent of non-convex adjustment.

The objective of this paper is to provide an assessment of the relationship between trade liberalization and factor adjustment of blue and white collar workers, as well as capital for Uruguayan manufacturing firms. Are sectors exposed to more foreign competition subject to larger adjustment costs? Are adjustment costs more important in the presence of surpluses, when the firm needs to reduce its current level of employment, or shortages, when it needs to increase it? How does the impact of higher international exposure differ for the adjustment of blue and white collar workers and capital? The answer to these questions will shed some light on whether more attention needs to be paid to facilitating factor adjustment as exposure to foreign competition increases, and whether the focus should be on hiring versus firing costs, capital versus labor, skilled versus unskilled workers, etc.

The literature on trade and adjustment costs generally focuses on what are called social adjustment costs measured by the impact of trade reforms on factor unemployment. Magee (1972) and Baldwin et al. (1980) measure the number of workers falling into unemployment after trade reform in the US, as well as the duration of their spells to provide estimates of the adjustments cost associated with unemployment. Their estimates suggest that social adjustment costs represent only 4 to 12 percent of the welfare gains associated with reforms. Matusz and Tarr (1999) in a review of the literature confirmed that the measured net labor employment effect of trade reforms is generally small.

It is tempting to extrapolate these conclusions to the case of the Uruguayan manufacturing sector facing rising competition from higher international exposure. There are two problems with this. First, most of the existing literature reviewed by Matusz and Tarr (1999) focuses on adjustment costs in labor markets of developed countries. Regulation of factor markets in Uruguay can be significantly more stringent than in the average OECD country. According to World Bank

[1] Dixit and Pindyck (1994) provide a general framework in which irreversibility, uncertainty and timing of investment decisions are integrated, and propose a view of the adjustment process in which the option nature of the firm's actions is emphasized.
[2] See Hammermesh and Pfann (1996) for a literature review.

(2010), Uruguay ranks 132th out of 183 countries in terms of easiness for starting a business, and 116th in terms of employment rigidity. Second, and more importantly, by focusing on the impact on unemployment (or employment levels) to capture factor adjustment costs, the literature assumes that firms are always at their desired levels of employment. If this is not the case, the small measured impact of trade opening on unemployment does not necessarily imply that adjustment costs are small, but rather that firms may be reluctant to fire or hire when subject to trade shocks, due precisely to the presence of very large factor adjustment costs (hiring and firing costs, training, loss of firm specific human or physical capital, etc.). Putting it differently, at least for surviving firms, one should expect trade reforms to have little impact on unemployment levels in the presence of large factor adjustment costs (or private adjustment costs in Matusz and Tarr 1999 terminology). In the extreme case where adjustment costs are infinite, there would be no impact of trade on employment, and the earlier literature would have concluded that there are no (social) adjustment costs. True, but opportunity costs in terms of production efficiency (and probably employment) due to firms facing infinite factor adjustment costs are large. The notion of adjustment costs used in this paper is a private, firm level measure of the gap between optimal and actual factor employment, and not a social measure of factor market flexibility as used in most of the theoretical literature (e.g. Matusz 1988).

Kambourov (2009) and Artuç et al (2010) are two recent papers performing structural empirical research into adjustment costs after trade reforms. Kambourov (2009) using a sample of countries including several Latin American ones reports that there is a significant increase in sectoral reallocation of workers in the years following a trade reform. However, high firing costs slows down or even eliminates this reallocation. Artuç et al (2010) estimates high average switching costs for workers, and a very high standard deviation of moving costs. Both were estimated to be several times average annual wages. The interpretation of these results is that most of US reallocation is not due to intersectoral wage differentials. Therefore, the adjustment of the labor market to a trade shock may be slow, taking several years.

Noeclassical industry-level trade theory (Ricardo, Heckscher-Ohlin) predicts that in response to changes in relative factor rewards, mobile factors reallocate from comparative disadvantage to comparative advantage industries. Homogeneous firm (new) trade theories with a geographical component determining firm's location under intra-industry trade also have implications for factor reallocation between the monopolistically competitive and the outside sectors. Lastly, (new-new) trade theory with heterogeneous firms predicts factor reallocations within industries and across firms. Bernard et al (2007) embed heterogeneous firms in a comparative advantage model and examine how country, industry and firm characteristics interact as trade costs fall in general equilibrium. Their approach generates predictions that contrast with neoclassical theories, showing that trade liberalization fosters simultaneous job creation and destruction in all industries, but gross and net job creation vary with country and industry characteristics. Comparative disadvantage industries experience net job destruction while comparative advantage industries enjoy net job creation, as job destruction due to exiting firms is lower than job creation by entrants and expanding higher productivity firms.

Although we do not specifically test the channels from trade to adjustment costs there is more than one way to think about them. We could think of a dynamic industry equilibrium model with heterogeneous firms where more productive firms capture larger market shares. Thus, there is an implicit minimum productivity threshold above which firms recover their fixed costs and survive. Trade liberalization would induce the entry of prospective firms (or importers) in response to the potential returns of high productivity draws. As a result there would be changes in the labor market producing changes in factor prices. Thus, in a model with heterogeneous firms trade liberalization is likely to induce reallocation of factors of production that are typically associated with adjustment costs. Some of these adjustment costs have to do with changes in the usage of production inputs and others have to do with changes in the identity of the particular employee or machine. As an example of the former we could think of disruptions to production provoked by rearrangement of workers assignments due to changes in total labor or capital use. As examples of the latter there are search costs, training costs and severance payments.

Another channel is related to changes in relative prices between tradeables and nontradables. In general, a trade liberalization process implies that capital goods become cheaper and more widely available (Muendler 2002 calls this *foreign input push*). Even if total employment is not altered, an increase in capital comes in hand with reallocation and restructuring of blue and white collar tasks. These adjustment costs are even higher when we consider the time necessary for machinery delivery and installation and personnel training. The irreversibility of investment stressed in the literature (Dixit and Pindyck (1994), Bertola and Caballero (2004)) makes firms reluctant to alter the capital level in the presence of uncertainty about future policies generating then adjustment costs that at least from this perspective may be higher for capital than employment.

If indeed trade liberalization provides cheaper capital goods, firms may find easier to close the gap between desired and actual level of capital. In doing so firms may speed up or slow the adjustment in other factors. In this way, changes in tariffs could affect adjustment costs via the marginal effect on factor shortages. A similar argument can be done with respect to labor demand. If there is an increase of displaced workers due to trade liberalization this would decrease the cost of search for expanding firms. Also most of the increased reallocation produced by trade liberalization happens within narrowly defined sectors. The cost of attracting and training reallocated workers formerly working in the same industry may be lower than the cost of attracting and training employees with no industry specific human capital. If this is the case it may be easier to close the gap between actual and desired employment and in doing so it may accelerate or postpone the adjustment of capital.

Our paper is based on Eslava *et al* (2005), which provides a novel approach to estimating adjustment functions that overcomes some drawbacks of the previous literature. Their methodology is based on the observation that employment and capital are not necessarily at their desired levels when firms face adjustment costs. At any point in time there is a gap between the actual and the desired level. The adjustment function of employment (capital) is defined as the percentage of the employment (capital) shortage that is actually closed when adjusting employment (capital) and is modeled as a function of the employment and capital shortages.

Though our work is an application of the Eslava *et al* (2005) methodology, there are several dimensions in which our paper is different from theirs. First, we have a specific emphasis in trade policy shifts. Trade policy has variation in time and firm (sector) dimensions and is therefore useful for identification of the associations that policy measures with variation only through time. Eslava *et al* (2005) look at the overall effect of policy by comparing adjustment functions before and after reforms, hence it may be difficult to separately identify other contemporaneous factors from the policy change. The way we set up our research question is different in that we incorporate trade policy as a part of adjustment function.

Second, we extend the analysis to three factors of production, allowing the separate study of blue-collar labor and white-collar labor, rather than overall employment. Either of the channels mentioned above affects both capital and employment so that adjustment of one factor would likely be affected by the adjustment needed in the other. Also they suggest that the adjustment cost may vary with the task performed by workers. Moreover, in their literature review Hamermesh and Pfann (1996) mention that there is evidence that the average cost of adjustment is larger for skilled than unskilled workers. Therefore it is important to allow the adjustment process of each factor to be affected by shortages of the others and to differentiate between white and blue-collar workers. Third, as a broad measure of welfare costs we estimate the gap between the desired and actual output produced by these adjustment costs. [3]

Finally, we use Uruguayan data, which reflect the most important policy and institutional changes related to the process of openness of the country to world trade. The Uruguayan economy evolved from inward looking, based on state interventionism and import substitution protectionist policies, towards an outward looking orientation, with more reliance on markets as resource allocation mechanisms and exports as the growth engine. A first phase of trade reform took place in the 1970s, accompanied by a quick financial liberalization process. Later, in the 1990s there was a process of trade liberalization (with simultaneous real exchange rate appreciation), combining gradual unilateral tariff reduction with the creation of Mercosur, an imperfect customs union between Argentina, Brazil, Paraguay and Uruguay. As a result, flows from and to these countries increased their share in Uruguay's trade.[4] A by-product of the trade liberalization process was that Uruguayan manufacturing firms switched to more capital intensive technologies as reported in Casacuberta, Fachola and Gandelman (2004).

Figure 1 shows the relative convergence to lower tariffs of most sectors of activity. This was achieved from a starting point with sizeable dispersion, with average industry tariffs between 20 and 50 percent. Descriptive statistics of the tariff level and average tariff change are presented in Table 1. We find that the average tariff was reduced significantly from an average of 43% to 14% between 1985 and 1995. On average, annual tariff changes accelerated from –2.1% before 1990 to –3.0% after 1990.

Our main results confirm the asymmetric nature of firms' adjustment process. Large shortages of one factor lead to less responsiveness in adjustment in the creation side of other factors but larger adjustment in the destruction side. Everything else equal it is easier to adjust in the presence of shortages (when the desired level is larger than the actual level). Adjustment costs reduce the volatility of factor usage but on average they implied an annual gap between desired and

[3] Other minor differences relate to estimation techniques. Our estimation of total factor of productivity is better shaped to take care of simultaneity problems. For the demand shock instead of estimating the inverse demand function by two stage least squares we estimate a system of supply and demand using three stage least squares.
[4] Total exports to Mercosur destinations went from 33% in 1989 to 46% in 1995; imports from the same countries climbed from 41% to 46% in the same period.

observed output of 2%. For most firms (those that do not want to triplicate or reduce to a third their factor use) blue collar adjustment costs are lower than white collar or capital adjustment costs. Sectors experiencing stronger trade liberalization adjust a lower fraction of the gap in the creation side (reducing shortages, i.e. hiring employees of investing) but a larger fraction in the destruction side (reducing surpluses, i.e. firing employees, scrapping or letting capital depreciate) Overall the association of higher international exposure with factor adjustment is stronger for blue collar workers than for white collar workers. While our paper lacks an empirical identification strategy to pinpoint the causal relationship between adjustment costs and trade openness, our estimation results describe an interesting empirical relationship between them.

The paper proceeds as follows. Section 2 presents the basic definitions of factor growth rates, desired factor growth rates and adjustment functions, and our basic estimated equations. Section 3 details the methodology to obtain these desired levels. Readers not interested in the technicalities of this procedure may skip this section. Section 4 introduces the data and Section 5 presents the results and analyzes the effects of policy changes in the firm's adjustment process. Section 6 concludes.

2. Labor and capital adjustment functions

In the traditional model without adjustment costs, the employment (capital) choice of the firms depends only on current shocks and future expectations. In the presence of adjustment costs, it also depends on past employment (capital) decisions and the gap between the actual and the "desired" level of employment (capital). We will use the notation L^*, H^* and K^* and L, H and K for desired and actual levels of blue collar labor, white collar labor and capital respectively. A key step in this methodology is the construction of the "desired" level.

Labor and capital inputs growth rates are defined as the ratio between input changes and the averages of their past and present values. These definitions follow Davis and Haltiwanger (1992), and Davis *et al* (1996).[5] Using Δ for growth rates, we have for $X = L, H, K$:

$$\Delta_{jt}^{X} = \frac{X_{jt} - X_{jt-1}}{\frac{1}{2}\left(X_{jt} + X_{jt-1}\right)} \tag{1}$$

Before a firm adjusts its factors of production, the employment (capital) desired rate of change at time t can be defined as the difference between the desired level of employment (capital) at time t and the actual level at time $t-1$. Paralleling the previously defined growth rates, the desired rate is expressed as a fraction of the average between the present desired level and the past observed level. Therefore, desired rates of change for each factor $X = L, H, K$ are:

[5] A feature of these growth rates is that they are symmetrical about 0 and restricted to finite values. With traditional growth rates a plant birth corresponds to an employment (capital) growth of positive infinity and a plant exit to a growth rate of –1. In contrast, with growth rates as used in this paper, a plant birth and a plant exit correspond to 2 and –2 growth rates. There is a monotonic relation between rates of growth so defined and the usual ones.

$$Z_{jt}^{X} = \frac{X_{jt}^{*} - X_{jt-1}}{\frac{1}{2}\left(X_{jt}^{*} + X_{jt-1}\right)} \tag{2}$$

A positive value corresponds to a shortage and a negative value to a surplus in factor use. We will term them generally "shortages", positive and negative respectively.

Following Eslava *et al* (2005) adjustment functions ($A^{H}{}_{jt}$, $A^{L}{}_{jt}$, $A^{K}{}_{jt}$, for blue and white collar employment and capital, respectively) are the fraction of desired rate of change that is actually closed. Hence for each factor $X = L, H, K$, they are defined as follows:

$$A_{jt}^{X} = \frac{\Delta_{jt}^{X}}{Z_{jt}^{X}} \tag{3}$$

Generally, the literature discusses arguments that explain why adjustment is triggered in a discontinuous or intermittent manner. Generally a range of inaction is obtained in which zero gross investment is optimal. [6] The main empirical device we use is the estimation of the percentage of adjustment as a function of the size of the gap to be closed, also known as "adjustment hazard function" [7]. We characterize adjustment functions in terms of the desired rates of change for all three factors, so that the adjustment function for each of them is not independent of the shortages/surpluses observed in the other two. We follow a parametric strategy in which we allow capital and labor adjustment to depend on their own shortage, on the other factors shortages and on interactive terms. In particular, the adjustment functions are not restricted to be linear and we allow for different intercept and slope for shortages and surpluses (positive or negative desired rates of growth). We do so because the sources of adjustment costs are different in the creation and destruction side. For instance, hiring new employees entails search, recruiting and training costs while firing current employees is associated with severance payments and eventual effects on the morale of the remaining ones. The basic specifications (omitting the asymmetric interactions for positive shortages) are:

$$A_{jt}^{H}(Z_{jt}^{H}, Z_{jt}^{L}, Z_{jt}^{K}) = \lambda_0 + \lambda_1\left(Z_{jt}^{L}\right)^2 + \lambda_2 Z_{jt}^{L} Z_{jt}^{K} + \lambda_3 Z_{jt}^{L} Z_{jt}^{H} + \lambda_4\left(Z_{jt}^{H}\right)^2 + \lambda_5 Z_{jt}^{H} Z_{jt}^{K} + \lambda_6\left(Z_{jt}^{K}\right)^2$$

$$A_{jt}^{L}(Z_{jt}^{H}, Z_{jt}^{L}, Z_{jt}^{K}) = \nu_0 + \nu_1\left(Z_{jt}^{L}\right)^2 + \nu_2 Z_{jt}^{L} Z_{jt}^{K} + \nu_3 Z_{jt}^{L} Z_{jt}^{H} + \nu_4\left(Z_{jt}^{H}\right)^2 + \nu_5 Z_{jt}^{H} Z_{jt}^{K} + \nu_6\left(Z_{jt}^{K}\right)^2 \tag{4}$$

$$A_{jt}^{K}(Z_{jt}^{H}, Z_{jt}^{L}, Z_{jt}^{K}) = \kappa_0 + \kappa_1\left(Z_{jt}^{L}\right)^2 + \kappa_2 Z_{jt}^{L} Z_{jt}^{K} + \kappa_3 Z_{jt}^{L} Z_{jt}^{H} + \kappa_4\left(Z_{jt}^{H}\right)^2 + \kappa_5 Z_{jt}^{H} Z_{jt}^{K} + \kappa_6\left(Z_{jt}^{K}\right)^2$$

[6] See Dixit and Pindyck (1994), Abel and Eberly (1994).

[7] See Caballero and Engel, (1993).

The adjustment functions are poorly defined for desired rates of growth close to 0. Therefore we rewrite equation (4) and assume an error term that may show intra group (industry) correlation. In practice the estimated models are the following:

$$
\begin{aligned}
\Delta H_{jt} &= Z_{jt}^{H}\left[\lambda_0 + \lambda_1\left(Z_{jt}^{L}\right)^2 + \lambda_2 Z_{jt}^{L} Z_{jt}^{K} + \lambda_3 Z_{jt}^{L} Z_{jt}^{H} + \lambda_4\left(Z_{jt}^{H}\right)^2 + \lambda_5 Z_{jt}^{H} Z_{jt}^{K} + \lambda_6\left(Z_{jt}^{K}\right)^2\right] + u_{jt}^{H} \\
\Delta L_{jt} &= Z_{jt}^{L}\left[v_0 + v_1\left(Z_{jt}^{L}\right)^2 + v_2 Z_{jt}^{L} Z_{jt}^{K} + v_3 Z_{jt}^{L} Z_{jt}^{H} + v_4\left(Z_{jt}^{H}\right)^2 + v_5 Z_{jt}^{H} Z_{jt}^{K} + v_6\left(Z_{jt}^{K}\right)^2\right] + u_{jt}^{L} \qquad (5) \\
\Delta K_{jt} &= Z_{jt}^{K}\left[\kappa_0 + \kappa_1\left(Z_{jt}^{L}\right)^2 + \kappa_2 Z_{jt}^{L} Z_{jt}^{K} + \kappa_3 Z_{jt}^{L} Z_{jt}^{H} + \kappa_4\left(Z_{jt}^{H}\right)^2 + \kappa_5 Z_{jt}^{H} Z_{jt}^{K} + \kappa_6\left(Z_{jt}^{K}\right)^2\right] + u_{jt}^{K}
\end{aligned}
$$

The significance of the non linear terms would indicate that a firm with a larger gap between desired and actual factor levels adjusts more. The adjustment is not a continuous and smooth process of minor factor changes.

Our policy exercises will be framed in terms of an extended version of equation (5). We focus basically on trade liberalization. The first step would be to estimate pre and post Mercosur adjustment functions as in Eslava *et al* (2005) to detect shifts in the response of firms arising from changes in the environment. However, since this does not allow isolating the effect of individual policies from other factors also present in the period, we prefer to study the interactions of a trade liberalization proxy (with variability at the time and firm level) with the adjustment functions. Moreover in the presence of tougher product market competition less flexible firms are likely to have higher probabilities of exiting, the surviving ones being those able to better adjust to the new market conditions. Any analysis of adjustment functions that is reduced to pre and post effects will not be able to discern between sample composition effects and changes in functional forms. To mitigate this critic it is important to have variation in policy variables both in the time and the cross section dimension. Specifically, we interact the intercept and each factor's own shortage terms (allowing for asymmetric effects in the creation and destruction sides) in the adjustment equations (5) with industry level change in tariffs.

We estimate parameters in equations (5) by panel fixed effects regressions. For each factor separately we generate a dummy variable that takes the value 1 when the shortage is positive and 0 otherwise (*Pos*). Interacting this dummy with the factor shortage and with the cube of the shortage we allow for asymmetric effects of positive and negative desired rates of growth, i.e. we allow for different levels as well as slopes of the adjustment for shortages and surpluses.

Standard errors in the adjustment cost functions do not have analytic expressions, and they depend on generated regressors (the factor shortages) which are functions of estimated firm-level variables such as the productivity and demand shocks. The standard errors in equations (5) were then estimated using a bootstrap procedure similar to that in Levinsohn and Petrin (2003). Firms were sampled in "blocks" obtaining 300 samples with replacement of size equal to the total number of firms ever present in the data. Once a firm was in the sample all the observations corresponding to the years in which it was present in the data were included in the data set. The whole estimation process (productivity, demand shock and compensation function) was carried out in each iteration, calculating desired and frictionless factor levels and obtaining parameters of equations (5).

3. Desired factor and output levels estimation

A description of the methodology for the estimation of the desired input levels follows, including a general optimization framework, the computation of desired input levels and the estimation of several required parameters. The reader interested mostly in the results of our exercises may skip this section and proceed directly to section 5 where results are presented.

3.1. Firm maximizing behavior

We assume a monopolistic competition framework in which firms have certain degree of market power. The inverse demand function for a firm is given by:

$$P_{jt} = Y_{jt}^{-\frac{1}{\eta}} D_{jt} \qquad (6)$$

where η is the elasticity of demand, D is a time and firm specific demand shock capturing all factors other than firms' own price affecting demand and Y is output demand.

The firm's production function is assumed to be:

$$Y_{jt} = A_{jt} K_{jt}^{\alpha} \left(L_{jt} \ell_{jt} \right)^{\beta} H_{jt}^{\mu} E_{jt}^{\gamma} M_{jt}^{\varphi} \qquad (7)$$

where K is capital, L is blue collar employment, ℓ are blue collar hours, H is white collar employment, E is energy, M is materials and A is a total factor productivity shock.

Firms face competitive factor markets with the following total costs for blue collar labor, white collar labor, capital, energy and materials:

$$\begin{aligned}
&\omega_L(L_{jt}, \ell_{jt}) = P_{Lt} L_{jt} \left(1 + P_{\ell_1 t} \ell_{jt}^{\delta} \right) \\
&\omega_H(H_{jt}) = P_{Ht} H_{jt} \\
&\omega_K(K_{jt}) = P_{Kt} K_{jt} \\
&\omega_E(E_{jt}) = P_{Et} E_{jt} \\
&\omega_M(M_{jt}) = P_{Mt} M_{jt}
\end{aligned} \qquad (8)$$

where P_H is the white collar wage, P_K is the user cost of capital, P_E is the per unit cost of energy and P_M is the per unit cost of materials. In the case of blue collar employees, total compensation is the product of employment L_{jt} times a wage function that depends on total hours ℓ_{jt}. This tries to capture the fact that the marginal wage is not constant. As the firm tries to increase hours per worker, it must resort to overtime hours and a premium must be paid at least for some workers. This function is indexed by parameters P_L (straight-time blue-collar wage), P_ℓ (overtime premium) and δ (marginal wage elasticity). [8]

Eliminating the firm subscript, the maximization problem in the presence of adjustment costs for a typical firm is:

$$\underset{\{K,L,\ell,H,E,M\}}{Max} \sum_t \beta^t E\left[P_t Y_t - \omega_L(L_t,\ell_t) - \omega_H(H_t) - \omega_K(K_t) - \omega_E(E_t) - \omega_M(M_t) - C\left(K_t, K_{t-1}, L_t, L_{t-1}, H_t, H_{t-1}\right)\right] \tag{9}$$

where $C\left(K_t, K_{t-1}, L_t, L_{t-1}, H_t, H_{t-1}\right)$ are adjustment costs for capital, blue collar and white collar labor. We specifically allow the adjustment cost not to depend only on the change of each factor, but also on the past levels of the others.[9]

3.2. Frictionless factor levels

To obtain the firm's desired factor input levels, we start by estimating the firm's frictionless factor demands. Frictionless levels correspond to the input levels that the firm would choose in absence of adjustment costs, and are derived from the firm's optimization problem. In the absence of adjustment costs, the dynamic problem of (9) can be rewritten as a static one.

$$\underset{K,L,\ell,H,E,M}{Max} P_t Y_t - \omega_L(L_t,\ell_t) - \omega_H(H_t) - \omega_K(K_t) - \omega_E(E_t) - \omega_M(M_t) \tag{10}$$

Maximization is carried out subject to firms being located on their demand curve. After taking logs, the first order conditions for both types of employment, hours, capital, energy and materials yield a system of six equations. Solving this system would give the long run factor demands as functions of prices and parameters. However the methodology proposed by Eslava *et al* (2005) assumes that for some of the production factors (hours, energy and materials) there are no adjustment costs. Hence, the frictionless levels of those inputs would coincide with the observed levels. Therefore, first order conditions for the remaining factors can be used as a reduced system of three equations and three unknowns. After solving it, we can write the log of the frictionless

[8] As in Caballero and Engel (1993), our functional form for the blue collar compensation implies that in the absence of employment adjustment costs, the firm would always choose the same number of hours per worker, and adjust to productivity and demand shocks only varying employment. Our data does not have information on white-collar hours, thus we have to assume a simpler compensation mechanism. In order to verify that our results are not produced by an asymmetric treatment of white and blue collars we experimented without considering blue-collar hours and effectively the main conclusions remained unaltered.

[9] We do not model explicitly adjustment costs. The issue of which of the suggested (or other) mechanisms is behind the link between policy changes and adjustment costs goes beyond the scope of the present paper.

levels of capital, blue-collar employment and white collar employment as functions of the parameters of the model to be estimated and observed variables. [10]

3.3. Desired factor levels

Frictionless levels are not the same as the desired ones. Both concepts differ in that the desired levels are the ones observed if adjustment costs are momentarily removed, while frictionless levels are those that would be observed in absence of adjustment costs in all periods. Bertola and Caballero (1994) introduce the concept of desired and frictionless capital and show that with irreversibility, Cobb-Douglas technology and iso-elastic demand but without adjustment costs, the two are equivalent up to an affine transformation. Caballero and Engel (1993) show that even with adjustment costs, if shocks are subject to near-i.i.d. increments (i.e., follow a process close to a random walk, or with a near unit root) the desired and frictionless labor or capital demands are proportional. In this framework desired levels can be approximated, up to a constant, by frictionless levels.

$$\begin{aligned} K^*_{jt} &= \overline{K}_{jt}\theta_{Kj} \\ L^*_{jt} &= \overline{L}_{jt}\theta_{Lj} \\ H^*_{jt} &= \overline{H}_{jt}\theta_{Hj} \end{aligned} \tag{11}$$

where $\left(K^*_{jt}, \overline{K}_{jt}\right)$, $\left(L^*_{jt}, \overline{L}_{jt}\right)$ and $\left(H^*_{jt}, \overline{H}_{jt}\right)$ are respectively desired and frictionless levels of capital, blue-collar and white collar employment. θ_{Kj}, θ_{Lj} and θ_{Hj} are firm specific constants to be estimated.

Following Caballero, Engel and Haltiwanger (1995, 1997) θ_{Kj}, θ_{Lj} and θ_{Hj} can be determined as the ratio between actual and frictionless capital, blue collar and white collar employment, for the year where investment and employment growth for each factor take their median values respectively. It is then implicitly assumed that for a firm, in the year the median employment growth and median investment are observed, the desired and the actual adjustment of employment and capital respectively coincide.

3.4. Desired to actual output gap

We find it useful to calculate the gap between "desired" and actual output as a measure of the magnitude of adjustment costs. As argued in the absence of adjustment costs the desired use of inputs may be higher or lower than the actual levels. Adjustment costs are in that sense natural stabilizers of output. For instance if there is a temporary positive shock to demand, firms wanting to profit from this positive shock are likely to increase their factor demand. Adjustment costs

[10] The explicit expressions are presented in Appendix 1.

reduce the size of this increase. On the contrary, on a recession firms may want to reduce the input use. Due to irreversibility in capital investments this may translate even in larger labor demand reductions. Again, adjustment costs buffer such changes. For instance, consider that the only (private) adjustment costs for the firm are severance payments. They may preclude a firm from reducing its labor use when facing a temporary recession. Once we have estimated desired employment and capital it is straightforward to obtain the firm's production at these factor usage levels and calculate the gap between desired and actual output.

To define the output gap we make the extra assumption that total factor productivity is an exogenous shock whose stochastic process is not dependent on the input levels. Given the production function and the previous assumption that desired and actual hours, materials and energy consumption coincide, desired output is:

$$Y_{jt}^{*} = K_{jt}^{*\,\alpha} \left(L_{jt}^{*} \ell_{jt} \right)^{\beta} H_{jt}^{*\,\mu} E_{jt}^{\gamma} M_{jt}^{\varphi} A_{jt} \qquad (12)$$

Subtracting firms' observed and desired output, and adding them across observations, it can be obtained a sector-wide desired to actual output gap. This aggregate measure is intended to give an order of magnitude, but may not be straightforwardly interpreted as a counterfactual comparison exercise on what would actually occur if adjustment costs were removed.

4. Data

In this paper we use annual establishment level observations from the Uruguayan Manufacturing Survey conducted by the Instituto Nacional de Estadística (INE) for the 1982-1995 period. The survey-sampling frame encompasses all Uruguayan manufacturing establishments with five or more employees.

The INE divided each four digit International Standard Industrial Classification (ISIC) sector in two groups. All establishments with more than 100 employees (*compulsory range*) were included in the survey; the random sampling process of firms with less than 100 employees satisfies the criterion that total employment of all the selected establishments must account at least for 60% of total sector employment according to the economic Census (1978 or 1988). We have 627 different establishments present in at least one period.[11]

With respect to employment categories the INE distinguishes between white and blue collar employment. [12] The first category includes personnel in operative activities involving mainly manual and physical tasks. The second includes workers performing mainly intellectual tasks, including administrative, clerical, sales-persons, managers, supervisors, directors, laboratory and research and development personnel.

Starting from the 1988 capital stock data from the economic census, the capital series is constructed using the perpetual inventory method back and forward (see the appendix for details).

[11] A more detailed analysis of the data is available in Casacuberta, Fachola and Gandelman (2004).
[12] *Obreros* and *empleados* in Spanish.

Our database includes input prices for materials and energy. Product prices are 4-digit industry indexes provided by the National Statistics Institute. White collar wage bill was divided by white collar employment for each establishment to obtain the white collar wage. For the user cost of capital we use a constant value of 10%. The only parameters remaining to be estimated are those of the compensation function for blue collar workers.

Finally, we use data on import tariffs for the period 1985-1995 from Casacuberta, Fachola and Gandelman (2004).

5. Estimation of firm level variables and compensation parameters

5.1. Demand shock estimation

The inverse demand function (6) is estimated in logs, and the demand shock recovered as the residual.

$$\widetilde{D}_{jt} = \ln \hat{D}_{jt} = \ln P_{jt} + \hat{\varepsilon} \ln Y_{jt} \tag{14}$$

where $\varepsilon = -\frac{1}{\eta}$. In order to identify the elasticity of the demand equation we estimate a two equation demand and supply system, using three stages least squares. Supply shifters include total factor productivity and a sector wage index, while time and industry effects are also included.[13] The estimated demand elasticity turned out to be -1.16 below Eslava *et al* (2005) (two stage least squares) estimate of -2.28 for Colombia. Given the smaller size of the Uruguayan market it is not surprising that firms face more inelastic demands and benefit for larger market power. Results are presented in Table 2.

5.2. Productivity shock estimation

We use Levinsohn and Petrin's (2003) methodology to obtain a measure of total factor productivity by estimating a production function where an electricity consumption variable is used to control for unobservables. Such method specifically controls for the simultaneity problem present in this type of estimations: input choices by firms conditional on the fact that they continue in activity depend on their productivity.

Given the production function specification in equation (7) we compute total factor productivity as:

[13] As suggested by a referee it could be argued that our shifters may not be a pure supply shock measure. Demand for product quality in differentiated goods markets and price-cost markups may enter the productivity estimate. In efficiency-wage models, sectoral wages respond to sectoral demand shocks. If this is so, three-stage demand estimation is not superior from an empirical point of view to the inverse demand function estimation used in Eslava *et al* (2005).

$$\widetilde{A}_{jt} = \widetilde{Y}_{jt} - \hat{\alpha}\widetilde{K}_{jt} - \hat{\beta}\left(\widetilde{L}_{jt} + \widetilde{\ell}_{jt}\right) - \hat{\mu}\widetilde{H}_{jt} - \hat{\gamma}\widetilde{E}_{jt} - \hat{\varphi}\widetilde{M}_{jt} \tag{13}$$

where $\hat{\alpha}, \hat{\beta}, \hat{\mu}, \hat{\gamma}$ and $\hat{\phi}$ are the estimated factor elasticities for capital, blue collar employment hours, white collar employment, electricity and materials respectively, and all variables are expressed in logs. The estimated coefficients of the production function are shown in Table 3. The null hypothesis of constant returns of scale is not rejected, though is not imposed. The standard errors were estimated across 100 bootstrapped samples.

5.3. Compensation function estimation

The postulated compensation function for blue collars is stated in (8). Bils (1987) and Cooper and Willis (2004) estimate for the U.S. the wage marginal elasticity δ to be *2*. Eslava *et al* (2005) working with Colombian firms calibrate δ to 2 and P_{ℓ} to the legally overtime premium and estimate from their data the straight-time wage P_L. We also calibrate δ to 2 and perform a nonlinear least squares procedure to estimate the parameters P_L, and P_{ℓ}. Table 4 shows the results of this estimation.

6. Results

In this section we present our adjustment function estimations. In the first subsection the main features of the adjustment process are analyzed, while the second subsection deals with the association between factor adjustment and trade liberalization.

6.1. Adjustment function estimation

In Figure 2 we display the histograms of the estimated desired rates of growth for blue and white collar workers and capital. Their distributions are roughly symmetric. Table 5 presents summary statistics on the desired, frictionless and actual input levels. All correlations are high suggesting the model predicts reasonably well. For the whole manufacturing sector the level of desired white collar jobs is 15% and the desired blue collar jobs and capital 10% above the actual ones.

Figure 3 shows the mean and median desired to actual output gap as a measure of the magnitude of adjustment costs. The mean gap for the whole period is 2%. This follows the business cycle in a procyclical manner. In 1982, Uruguay suffered a deep exchange rate and financial crisis that led to three years of recession. In such years desired output was below the observed one. In 1985, the economy started to recover but desired output was still lower than the actual one. The next five years are expansionary years and firms tend to desire more employment and capital than what they actually were hiring implying a positive gap between desired and actual output. Due to inflation the government in 1990 undertook contractionary fiscal policies that led to a halt in GDP growth that was resumed two years later. This implied negative gaps in the early nineties and positive ones in the last years of our sample. Table 6 presents the average desired to actual output gap by sector, showing significant variation between them. The larger gaps are for the wood and furniture and non-metal mineral product sectors.

Table 7 reports the estimated coefficients of the adjustment functions (equation 5 with openness interactions). Comparing the equations for different factors, none displays an intercept significantly different from zero except blue collar labor. This means that for small shortages in the negative side (i.e. surpluses), firms would adjust more (i.e. fire) in the case of blue collar labor. The intercept of both blue and white collar labor functions show a positive shift when shortages are on the positive side, i.e. when firms should create jobs to bridge the gap. The intercept of the capital adjustment function is not significantly different from zero in any case.

Both in the creation and the destruction side, the slopes for white collar are significantly different from zero, while for blue collar labor they are not. [14] This implies, roughly, more adjustment in blue collar when shortages are small in absolute value (larger intercept of blue collar function) and more adjustment in white collar when shortages are larger in absolute value (larger slopes in the case of white collar). Such features can be seen as related to the differences in adjustment costs for each factor. Labor unions tend to be stronger in industries more intensive in blue collar labor inducing higher adjustment costs on the destruction side when employment surpluses are large; i.e. they will produce lower adjustment when the desired rate of growth is large in the destruction side. When the shortage is small in absolute value, adjustment is lower in white collar than in blue collar. Conversely, if the shortage is large in absolute value, a larger proportion of the gap is closed for white collars than for blue collars.

White collar labor may include workers with more specific and difficult to create human capital, hence firms may be willing to accept small shortages without adjusting, but the adjustment will be fuller when those become large in absolute value. For instance, consider a firm that has more clerks that needed, but these clerks are familiar with the workings of the firm: if this shortage is not too large, the firm may prefer to keep these extra workers. On the other hand, if blue collars have less specific training, they may be more easily disposed. On the creation side, hiring an extra clerk implies higher training costs; hence the firm may prefer to use the existent workers more intensively if the shortage is small. If the shortage becomes large enough, the cost of the extra hours will be higher than the training cost of the newly hired white collar workers. This search and training costs may include a fixed cost that can be covered only when the percentage of the gap closed is large enough.

The capital adjustment function is similar in shape to the white collar: larger slope in the destruction side than in the creation side, though there is no increased intercept in creation.

The significance of the factor creation interactions variable (*Pos*) shows that the adjustment function is asymmetric with respect to positive and negative desired rates of growth in the intercept for blue collar labor, in the intercept and the slope for white collar labor, and just in the slope for capital.

[14] Comparisons of magnitudes of coefficients refer to 95% confidence intervals.

Another asymmetry is given by the fact that estimated adjustment functions display smaller slopes in the creation side than in the destruction side. Differences in slopes can be understood together with differences in the intercepts. The higher intercept in the creation side indicates higher adjustment for firms with smaller factor shortages, while a relatively flat slope of the adjustment schedule shows that they are able only to undertake smaller adjustments when there is a high positive shortage. On the contrary, the lower adjustments for small surpluses are associated with firms closing higher percentages of the gaps when surpluses become large enough in absolute values.

Adjustment functions are graphed in Figure 4. Since our specification implies that besides the policy interactions every shortage in every factor and the interactions between them can potentially have an effect on the adjustment of each factor, we display baseline estimations for each of them setting the desired rates of growth of other factors at zero and assuming no changes in tariffs. The percentage of adjustment is plotted as a function of the shortage. Negative desired rates of growth indicate that the past level of the input is above the desired one (there is a factor *surplus*), hence to close this gap the firm needs to decrease this factor, and finds itself in the job or capital destruction side. Conversely, positive desired rates of growth show a past level of the input below the desired one (a factor *shortage*), hence if the firm wants to close the gap, it will be in the factor creation side, i.e. it will invest or hire.

Figure 4 shows the asymmetric behavior in the adjustment process. First, for small values of the observed shortage, white and blue collar employment adjustment functions show an upward shift in the positive side. Firms tend to adjust a larger fraction of the gap between desired and actual employment when the observed levels are below the desired ones, i.e. firm finds it easier to create labor than to destroy it except when the destructive adjustment is large. Note that for desired rates of growth in absolute value below 1, firms close a larger fraction of the gap of blue collar workers than the gap in other factors. A shortage of 1 or -1 corresponds to firms desiring to triplicate or reduce to one third the actual use of the input. Therefore, for most firms, blue collar adjustment costs are lower than adjustment in other factors.

In the three regressions there is at least one significant cross product term. We can infer that, as conjectured, shortages or surpluses of other factors are relevant to understand the adjustment process. The negative sign of these cross desired rates of growth terms imply that large shortages of one factor lead to less responsiveness in adjustment in the creation side of other factors but larger adjustment in the destruction side. In simpler words, for a firm whose desired level of two factors is above the current level, the larger the shortage in one factor, the lower the adjustment in the other. Suppose now a firm desiring to have a lower level of two factors than their actual value, the larger the surplus in one factor the larger the adjustment in the other. That is to say, when firms want to hire more it is cheaper to adjust one factor at a time but when firms want to reduce employment or scrap capital it is cheaper to reduce the use of both factors together.

Finally, the effects of the shortage of the other factors in the adjustment function are captured both by the direct effect and the cross product effects terms, but their dominant effect comes mostly from the latter. To observe the effect of the rest of the factors in each adjustment function, figure 5 shows separately the adjustment function of each factor, where the desired rates of growth in the other factors are set at their mean values, and their mean values plus and minus one standard deviation respectively (and no change in tariffs is assumed). A negative sign of the coefficients of the cross product of the desired rates of growth (see Table 7) is associated with higher shortages of the other factors, the higher the adjustment in the destruction side, and the lower the adjustment in the creation side (see figure 5). Many firms downsized and even exited over the period of trade liberalization. This implied the simultaneous destruction of labor (both white and blue collar) and capital. This explains why higher desired rates of growth in absolute value for capital (white collar employment) provoke higher adjustment on white collar (capital).

6.2. The association between trade liberalization and factor adjustment

In all the regressions reported in Table 7 at least one policy interaction is significant. In order to assess how important are the differences in adjustment with varying levels of trade liberalization, in Figure 6 we simulate the predicted adjustment for different levels of changes in tariffs (0, 2 and 4 points tariff reductions assuming zero shortage of other factors).

Looking at the plotted adjustment functions, while for capital the association of tariff reductions with adjustment functions is really minor, a pattern emerges for both types of labor, in which the fraction of the gap actually adjusted decreases in the creation side, while increases in the destruction side. For white collars this is produced by a statistically significant change in the intercept while for blue collars it is produced by a change on the slope, also statistically significant. Firms in sectors that experienced higher tariff reductions were able to adjust a larger proportion of their surpluses than those not so exposed. It is interesting that this result is produced mostly for low levels of desired rates of growth, while for blue collar is for higher desired rates of change. Although, there is a small change in the plotted slope for white collars, this change is not statistically significant, therefore the hill shape the adjustment is not affected and changes should be considered more as parallel shifts. On the creation side it was the opposite: firms with lower tariff reductions adjusted a larger proportion of their shortages.

A warning of caution may be issued with respect to interpreting causally the association we find. Protected sectors are typically less competitive industries and are prone to reduce net employment even in the presence of trade protection. [15] An alternative view might be that protection may in fact destroy jobs, rather than create. If shocks to firm are iid, our result implies that protection will lead to lower levels of employment. The reason may have to do with firms' expectations. For instance suppose there is a generalized positive demand shock. A firm in a highly protected sector will not adjust completely in the presence of adjustment costs (e.g., firing workers) unless the government has credibly committed to maintain protection. If there is any risk that the tariff will go down, then the firm may be more reluctant to hire many workers than a similar firm in other sector that is not exposed to the risk of the government reducing tariffs. The same applies on the job destruction side. A highly protected firm that suffers a negative shock will be more likely to fire workers if the government's tariff is not a credible permanent policy.

[15] The correlation coefficient across firms of tariffs and our total factor productivity measure was -0,09 in 1985, i.e. the Uruguayan government tended to protect more the less productive firms/sectors before the openness process.

Changes in tariffs are generally considered not to be exogenously determined. In our case this problem is less severe due to the fact that Uruguay is a relatively minor player integrated with its larger neighbor economies in Mercosur. Hence the common external tariff and therefore the changes in Uruguayan tariffs to converge to the trade block protection level are basically affected by Argentinean and Brazilian political players and beyond control for local firms.[16]

During the sample period there was a trend of tariff reductions in most industries, with the greatest reduction in the industries that were initially most protected. These tariff changes were for the most part predictable in advance (especially after the signature of the Mercosur Treaty in 1990). The nature of factor adjustment due to such a predictable, and probably permanent, change in the economic environment is likely to be different from factor adjustment in response to fluctuations in demand or input prices that occur over the business cycle. [17] Firms would have incorporated expectations regarding how the tariff reductions would affect the product demand curve they face and probably also how they would affect input prices relevant to their factor employment decisions. In this line, sectors that were initially more protected and predict that will have to downsize will not create jobs nor capital even if they face a temporary positive shock. The long run tendency dominates their decision and therefore more protection may be associated with less adjustment on the creation side. Similarly, more protected sector that predict lower levels of employment and capital in the medium turn will more likely destroy factors in the face of a temporary negative shock since they know that the general tendency goes in this direction. In a framework as the one here studied with a probably predictable trade liberalization tendency, tariff protection is associated with more adjustment on the destruction side and less in the creation side.

7. Conclusions

This paper uses micro data to improve our understanding of the association of policy measures and production factors adjustment. On the one hand, the paper finds evidence supporting a number of regularities highlighted by the previous literature on adjustment functions.

Our investigation confirms that aggregate investment and job creation might not be considered the result of smooth and continuous microeconomic decisions. Individual adjustment constraints depart significantly from the constraints implicit in the quadratic adjustment cost model. There are several sources of irreversibilities (technological, market-induced, increasing returns in the adjustment technology). The evidence provided seems to confirm a pattern that has important nonlinear features, hence consistent with such constraints.

Adjustment costs faced by capital, white and blue collar labor are non trivial in the Uruguayan manufacturing sector, which has consequences in terms of factor unemployment and economic efficiency. For white and blue collar employment, they tend to be larger in the presence of small surpluses (when the firms need to fire workers) than in the presence of small shortages (when the firm needs to hire workers). However, for large surpluses and shortages (e.g., exit and entry of

[16] This is discussed in more detail in Casacuberta, Fachola and Gandelman (2004)

[17] We thank an anonymous referee for this point.

firms), adjustment costs are larger on the entry side. Overall, most firms find that the factor of production with the lowest adjustment costs is blue collar employment.

The existence of adjustment costs implies that the desired levels of white and blue collar employment and capital often deviate from the observed ones. In our data these deviations imply that yearly gaps might be above 10%. To have an idea of the magnitude of the effects of adjustment costs, it is useful to consider that for the fourteen years covered in this study the average gap between desired and actual output is 2%.

On the other hand, the paper intended to assess the association between trade liberalization and firms' adjustment process. The constraints arising from the adjustment cost functions may become an important part of the policy analysis. Our results point to a significant shift in adjustment functions for all the production factors associated with the increased liberalization that followed the Mercosur treaty. Specifically, trade policy variables measured by tariffs changes significantly shifted adjustment functions. The larger the trade liberalization experience by a firm the lower the fraction of the gap adjusted in the creation side (hiring employees of investing) and the higher the fraction in the destruction side (firing employees or scrapping capital), particularly for blue collar labor. Sectors facing larger tariff changes, adjust less in the creation side, particularly for blue collars, and more on the destruction side. In the context of tariff reductions of Mercosur, those sectors more highly protected were probably those that faced the largest tariff reductions. Overall the relationship between trade liberalization and adjustment functions is stronger for blue collar workers than for white collar workers.

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2. Appendix 1. Derivation of frictionless factor levels

Maximizing equation (10) subject to firms being located on their demand curve, the first order conditions for both types of employment, hours, capital, energy and materials (after taking logs) yield the following system of equations, where $\overline{X}$ denotes the frictionless levels, $\tilde{\overline{X}} = ln\,\overline{X}$ for production factors and $\tilde{P} = ln\,P$ for input prices, and time subscripts were omitted to simplify notation):

$$\tilde{\overline{K}} = \frac{\frac{\eta}{\eta-1}\left(-ln\frac{\eta-1}{\eta} - \tilde{D}\right) + \frac{\eta}{\eta-1}\left(\tilde{P}_K - ln\,\alpha\right) - \beta\left(\tilde{\overline{L}} + \tilde{\overline{\ell}}\right) - \mu\tilde{\overline{H}} - \gamma\tilde{\overline{E}} - \varphi\tilde{\overline{M}} - \tilde{\overline{A}}}{\alpha - \frac{\eta}{\eta-1}} \qquad \text{(A1)}$$

$$\tilde{\overline{L}} = \frac{\frac{\eta}{\eta-1}\left(-ln\frac{\eta-1}{\eta} - \tilde{D}\right) + \frac{\eta}{\eta-1}\left(\tilde{P}_L - ln\,\beta\right) + \frac{\eta}{\eta-1}\left(1 + \tilde{P}_\ell\,\overline{\ell}^{\delta}\right) - \alpha\tilde{\overline{K}} - \beta\tilde{\overline{\ell}} - \mu\tilde{\overline{H}} - \gamma\tilde{\overline{E}} - \varphi\tilde{\overline{M}} - \tilde{\overline{A}}}{\beta - \frac{\eta}{\eta-1}} \qquad \text{(A2)}$$

$$\tilde{\overline{\ell}} = \frac{\frac{\eta}{\eta-1}\left(-ln\frac{\eta-1}{\eta} - \tilde{D}\right) + \frac{\eta}{\eta-1}\left(\tilde{P}_L - ln\beta\right) + \frac{\eta}{\eta-1}\left(\tilde{P}_\ell + \tilde{\overline{L}}\right) + \frac{\eta}{\eta-1}ln\delta - \alpha\tilde{\overline{K}} - \beta\tilde{\overline{L}} - \mu\tilde{\overline{H}} - \gamma\tilde{\overline{E}} - \varphi\tilde{\overline{M}} - \tilde{\overline{A}}}{\beta - \delta\frac{\eta}{\eta-1}} \qquad \text{(A3)}$$

$$\tilde{\overline{H}} = \frac{\frac{\eta}{\eta-1}\left(-ln\frac{\eta-1}{\eta} - \tilde{D}\right) + \frac{\eta}{\eta-1}\left(\tilde{P}_H - ln\,\mu\right) - \alpha\tilde{\overline{K}} - \beta\left(\tilde{\overline{L}} + \tilde{\overline{\ell}}\right) - \gamma\tilde{\overline{E}} - \varphi\tilde{\overline{M}} - \tilde{\overline{A}}}{\mu - \frac{\eta}{\eta-1}} \qquad \text{(A4)}$$

$$\tilde{\overline{E}} = \frac{\frac{\eta}{\eta-1}\left(-ln\frac{\eta-1}{\eta} - \tilde{D}\right) + \frac{\eta}{\eta-1}\left(\tilde{P}_E - ln\,\gamma\right) - \alpha\tilde{\overline{K}} - \beta\left(\tilde{\overline{L}} + \tilde{\overline{\ell}}\right) - \mu\tilde{\overline{H}} - \varphi\tilde{\overline{M}} - \tilde{\overline{A}}}{\gamma - \frac{\eta}{\eta-1}} \qquad \text{(A5)}$$

$$\tilde{\tilde{M}} = \frac{\frac{\eta}{\eta-1}\left(-\ln\frac{\eta-1}{\eta}-\tilde{D}\right)+\frac{\eta}{\eta-1}\left(\tilde{P}_M-\ln\varphi\right)-\alpha\tilde{\tilde{K}}-\beta\left(\tilde{\tilde{L}}+\tilde{\tilde{\ell}}\right)-\mu\tilde{\tilde{H}}-\gamma\tilde{\tilde{E}}-\tilde{\tilde{A}}}{\varphi-\frac{\eta}{\eta-1}} \tag{A6}$$

Assuming there are no adjustment costs for hours, energy and materials, the frictionless levels of those inputs coincide with the observed levels. Therefore, equations (A1), (A2) and (A4) form a system of three equations and three unknowns. After solving it, the log of the frictionless levels of capital, blue-collar employment and white collar employment are written as functions of the parameters to be estimated and observed variables as follows:

$$\tilde{\tilde{K}} = \frac{\frac{\eta}{\eta-1}\left(-\ln\frac{\eta-1}{\eta}-\tilde{D}\right)-\beta\tilde{\tilde{\ell}}-\gamma\tilde{\tilde{E}}-\varphi\tilde{\tilde{M}}-\tilde{\tilde{A}}+\left(\frac{\eta}{\eta-1}-\beta-\mu\right)\left(\tilde{P}_K-\ln\alpha\right)+\beta\left[\tilde{P}_L-\ln\beta+\left(1+P_\ell\bar{\ell}^{\delta}\right)\right]+\mu\left(\tilde{P}_H-\ln\mu\right)}{\alpha+\beta+\mu-\frac{\eta}{\eta-1}} \tag{A7}$$

$$\tilde{\tilde{L}} = \frac{\frac{\eta}{\eta-1}\left(-\ln\frac{\eta-1}{\eta}-\tilde{D}\right)-\beta\tilde{\tilde{\ell}}-\gamma\tilde{\tilde{E}}-\varphi\tilde{\tilde{M}}-\tilde{\tilde{A}}+\left(\frac{\eta}{\eta-1}-\alpha-\mu\right)\left[\tilde{P}_L-\ln\beta+\left(1+P_\ell\bar{\ell}^{\delta}\right)\right]+\alpha\left(\tilde{P}_K-\ln\alpha\right)+\mu\left(\tilde{P}_H-\ln\mu\right)}{\alpha+\beta+\mu-\frac{\eta}{\eta-1}} \tag{A8}$$

$$\tilde{\tilde{H}} = \frac{\frac{\eta}{\eta-1}\left(-\ln\frac{\eta-1}{\eta}-\tilde{D}\right)-\beta\tilde{\tilde{\ell}}-\gamma\tilde{\tilde{E}}-\varphi\tilde{\tilde{M}}-\tilde{\tilde{A}}+\left(\frac{\eta}{\eta-1}-\alpha-\beta\right)\left(\tilde{P}_H-\ln\mu\right)+\beta\left[\tilde{P}_L-\ln\beta+\left(1+P_\ell\bar{\ell}^{\delta}\right)\right]+\alpha\left(\tilde{P}_K-\ln\alpha\right)}{\alpha+\beta+\mu-\frac{\eta}{\eta-1}} \tag{A9}$$

3. Appendix 2. Capital stock data

To construct the establishment capital stock series, we follow a methodology close to Black and Lynch (2001). The 1988 Census reports information on the capital stock. We use machinery capital. We avoid overestimation of the amount of depreciation by calculating an average depreciation rate by industrial sector and year. The resulting depreciation rate is then used for all firms within each sector yearly. We further exclude the value of assets sold in our measure of capital, assuming assets have been totally depreciated at that point. Thus, the equation for estimating the capital stock for years later than 1988 is:

$$K_{jit} = K_{jit-1} + I_{jit} - \delta_{it} K_{jit-1} \quad \text{(A10)}$$

with

$$\delta_{it}^{x} = \frac{\sum_{j} D_{jit}}{\sum_{j} K_{jit}} \quad \text{(A11)}$$

where *j* indexes firms; *i* the industrial sector, *t* the year. *K* is the capital stock; *I* is amount invested; δ is the depreciation rate; and *D* is depreciation in pesos.

For years before 1988, the equation is reversed and each year's capital is obtained by subtracting each year's investment and applying a depreciation factor. The depreciation rate before 1988 was not available and was estimated using 1988 data. We ran a simple OLS model for the log of total depreciation conditional on the log of gross output, capital stock, total hours and electricity usage. Using this model we predicted the before 1988 depreciation levels.

$$K_{jit-1} = \left(K_{jit} - I_{jit}\right) \cdot \left(\frac{1}{1 - \hat{\delta}_{jit}}\right) \quad \text{(A12)}$$

4. Tables

Table 1
Policy variables
Descriptive statistics

	tariff (%)	Tariff change
1982	.	.
1983	.	.
1984	.	.
1985	42.53	.
1986	38.96	-3.47
1987	35.49	-3.46
1988	32.64	-3.46
1989	32.07	-0.57
1990	31.50	-0.57
1991	24.59	-6.97
1992	20.68	-3.91
1993	17.09	-3.54
1994	17.11	0.02
1995	14.01	-3.14
All period		
Mean	26.3	-2.8
standard dev	9.9	2.7
Percentile 50	24.9	-2.9
Percentile 90	40.0	0.1
Before 1990		
Mean	34.7	-2.1
standard dev	8.2	1.8
Percentile 50	34.6	-2.2
Percentile 90	44.5	0.3
1990 and after		
Mean	21.3	-3.0
standard dev	6.9	2.9
Percentile 50	19.8	-3.1
Percentile 90	31.4	0.0

Table 2
Demand shock estimation
Three-stage least squares regression

	Obs	Parameters
Demand equation	5903	9
Supply equation	5903	16
	Coef,	**Std. Err.**
Demand equation		
Price	-1,156*	0,619
Supply equation		
Price	0,863*	0,520
Total factor productivity	0,006*	0,003
Wage Index	-0,376**	0,166

Note: Dependent variable is gross output.
Endogenous variables: gross output and price.
Exogenous variables not reported: year dummies (supply) and 3 digit ISIC industry dummies (demand)
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 3
Levinsohn-Petrin productivity estimation

	Coefficients	Std. Err.
White collar	0,148***	0,026
Blue collar hours	0,234***	0,036
Materials	0,314***	0,053
Machinery capital	0,120*	0,063
Electricity	0,200***	0,088
Number of observations	5903	
Number of establishments	685	
Wald test of constant returns to scale:	Chi2 =1,51 (p = 0,22)	

Note: Dependent variable is gross output. All variables are in logs
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 4
Compensation function estimation

Non linear least squares

	Coefficient	Std. Err.
P_L	0,816***	0,016
P_ℓ	1,24E-07***	6,36E-09
δ	2	
Number of obs	6198	
R-squared	0.832	
Adj R-squared	0.844	

Note: * Parameter delta calibrated to 2.
significant at 10%; ** significant at 5%; *** significant at 1%

Table 5
Summary statistics: actual, desired and frictionless factor levels

Mean values

	Observations	Mean	Std. Dev.
Desired white collar labor	5512	37	75
Actual white collar labor	5512	32	63
Desired blue collar labor	5512	115	208
Actual blue collar labor	5512	105	168
Desired capital level	5512	275333	788947
Actual capital level	5512	249379	657317

Pariwise Correlations:

	Frictionless	Desired	Actual
Frictionless white collar labor	1.00		
Desired white collar labor	0.75	1.00	
Actual white collar labor	0.72	0.85	1.00

	Frictionless	Desired	Actual
Frictionless blue collar labor	1.00		
Desired blue collar labor	0.66	1.00	
Actual blue collar labor	0.65	0.88	1.00

	Frictionless	Desired	Actual
Frictionless capital level	1.00		
Desired capital level	0.66	1.00	
Actual capital level	0.63	0.82	1.00

Table 6
Desired to Actual Output Gap by sector

Sector (ISIC Rev. 2)	Average
Food. Beverage and tobacco	1,7%
Textile and garment	2,6%
Wood and furniture	4,6%
Paper and printing	-4,6%
Chemical	2,8%
Non metal mineral products	4,2%
Basic metal	3,8%
Machinery and equipment	3,0%
Other sectors	0,1%
Total	2,2%

Table 7
Estimated parametric adjustment functions

	White collar adjustment	Blue collar adjustment	Capital adjustment
Constant	0.026	0.167	0.062
	[0,040]	[0,059]***	[0,047]
Constant*Pos	0.196	0.116	0.038
	[0,067]***	[0,061]*	[0,062]
$(Z^H)^2$	0.201	0.032	0.006
	[0,035]***	[0,032]	[0,019]
$(Z^H)^2$*Pos	-0.076		
	[0,039]*		
$(Z^L)^2$	-0.006	0.044	-0.022
	[0,022]	[0,036]	[0,032]
$(Z^L)^2$*Pos		0.026	
		[0,021]	
$(Z^K)^2$	-0.009	0.033	0.179
	[0,014]	[0,019]*	[0,019]***
$(Z^K)^2$*Pos			-0.119
			[0,014]***
Z^H*Z^L	-0.047	-0.002	-0.013
	[0,026]*	[0,025]	[0,018]
Z^H*Z^K	-0.025	-0.013	0.016
	[0,025]	[0,021]	[0,023]
Z^L*Z^K	0.036	-0.040	-0.063
	[0,022]	[0,024]*	[0,026]**
Constant*Open	-0.019	-0.002	-0.017
	[0,007]***	[0,009]	[0,008]**
Constant*Pos*Open	0.012	-0.007	0.020
	[0,011]	[0,011]	[0,009]**
$(Z^H)^2$*Open	0.005		
	[0,007]		
$(Z^H)^2$*Pos*Open	0.006		
	[0,008]		
$(Z^L)^2$*Open		-0.015	
		[0,009]*	
$(Z^L)^2$**Pos*Open		0.027	
		[0,010]***	
$(Z^K)^2$*Open			0.008
			[0,008]
$(Z^K)^2$*Pos*Open			-0.008
			[0,005]
Observations	4278	4278	4278
Number of id	627	627	627
R-squared	0.33	0.31	0.31

Note: This is a panel fixed effect regression. Constant*Pos: Dummy=1 if Shortage is positive. ZL. ZH. ZK are the desired rates of growth for white collar, blue collar and capital. Open is the annual change in tariff levels. Standard errors in brackets calculated by bootstraping.
* significant at 10%; ** significant at 5%; *** significant at 1%

Figure 1. Average tariff by sector of activity (ISIC Rev. 2)

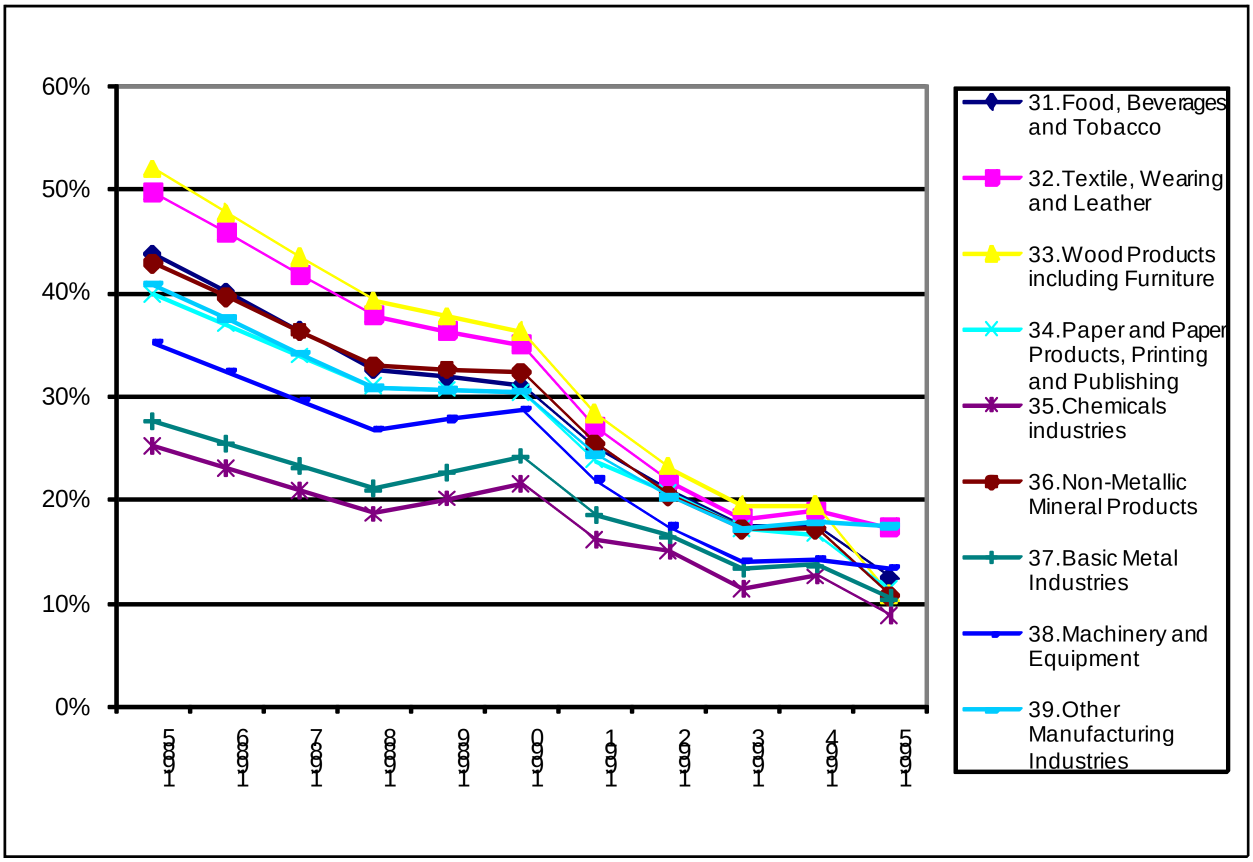
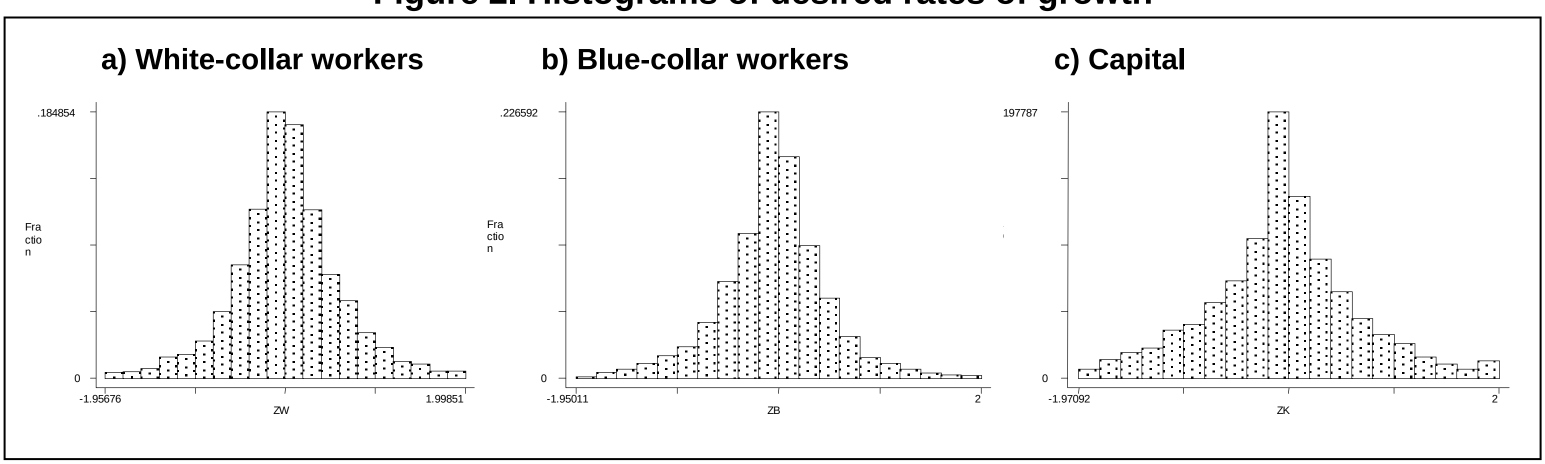


Figure 2. Histograms of desired rates of growth



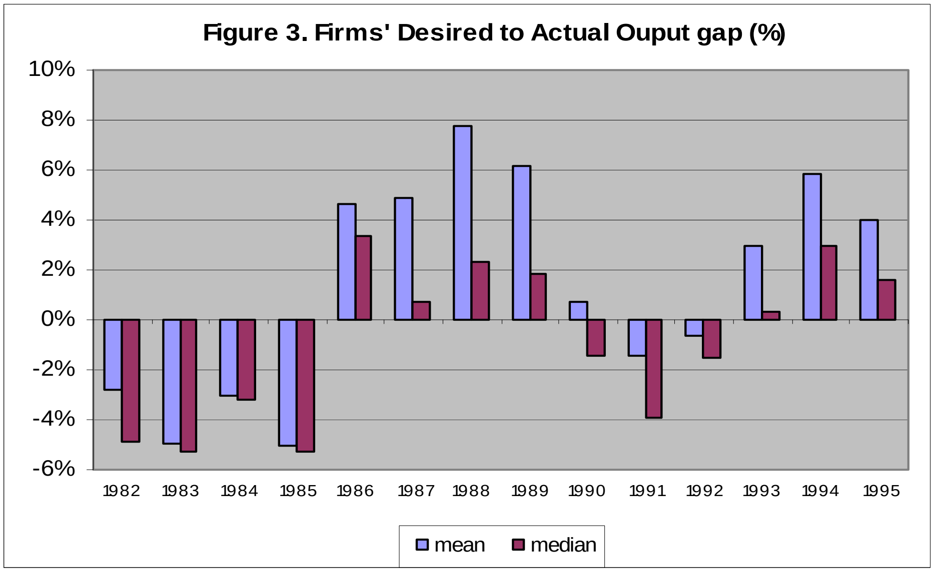


Figure 3. Firms' Desired to Actual Ouput gap (%)
10%
8%
6%
4%
2%
0%
-2%
-4%
-6%
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
mean
median

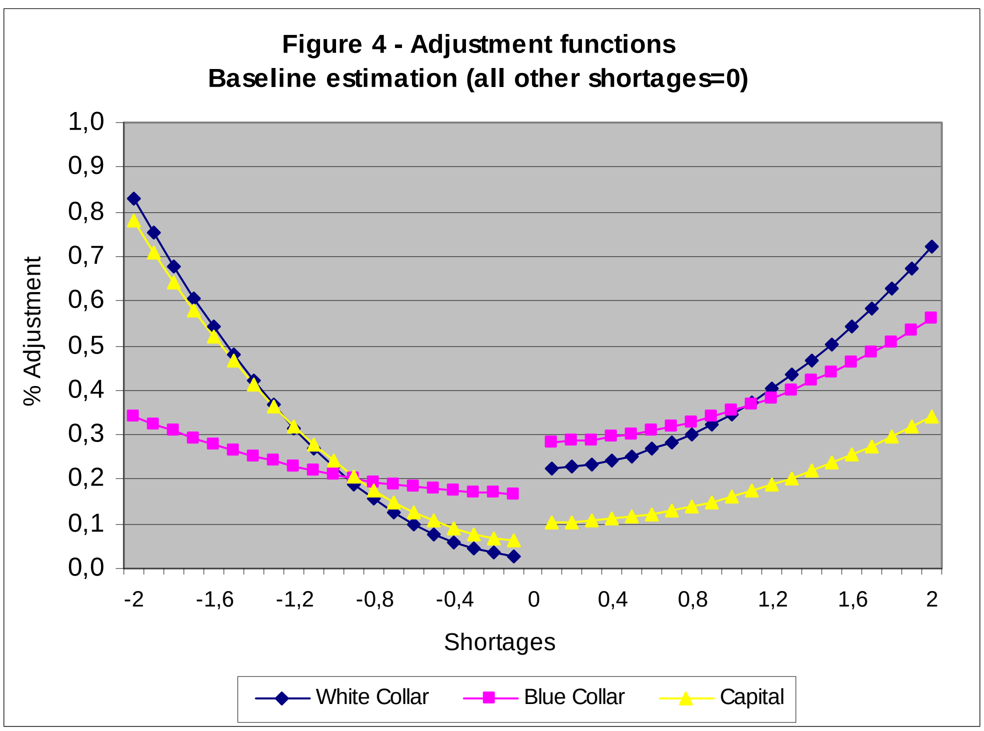
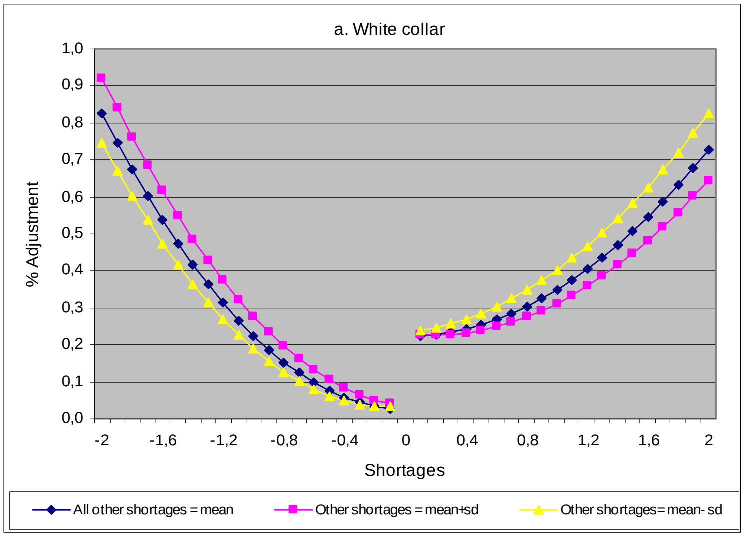
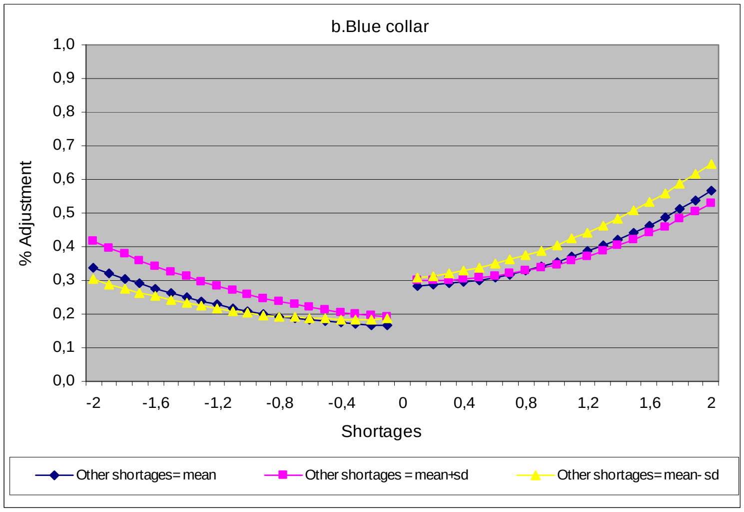


Figure 4 - Adjustment functions
Baseline estimation (all other shortages=0)
% Adjustment
1,0
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0,0
-2
-1,6
-1,2
-0,8
-0,4
0
0,4
0,8
1,2
1,6
2
Shortages
White Collar
Blue Collar
Capital

Figure 5. Relationship between other factor shortages and adjustment functions





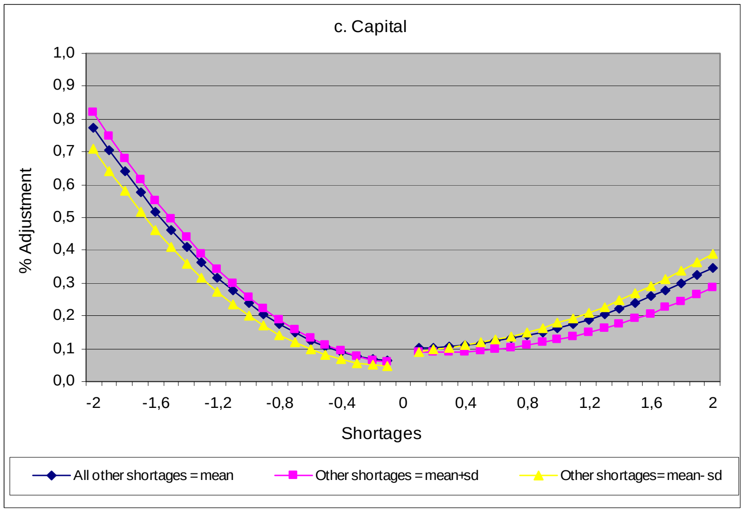


Figure 6. Relationship between trade liberalization and adjustment functions