Job Creation and Investment in Imperfect Capital and Labor Markets*

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Abstract.- This paper shows that liquidity constraints restrict job creation even with flexible labor markets. In a dynamic model of firm investment and demand for labor with imperfect capital markets, represented as a constraint on dividends, and imperfect labor markets, contained in legal firing costs applicable to some workers, firms use flexible labor contracts to alleviate financial constraints. The optimal policy rules of the theoretical model are integrated into a maximum likelihood procedure to recover the model's behavioral parameters. Data for the estimation come from the CBBE (Balance Sheet data from the Bank of Spain). I evaluate the effects of removing one imperfection at a time, and show that the relaxation of financial constraints produces
(i) more job creation than the elimination of labor market rigidities, and
(ii) a substantial increase in firm investment, which does not happen if only labor market rigidities are removed.

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1 Introduction

The removal of labor market rigidities has been the cornerstone of labor policies in several Western European economies in the eighties. Policy measures for labor market liberalization included reducing firing costs, lowering government intervention in wage determination and reducing unemployment transfers. In particular, most of the observed reforms did not attempt to reduce the costs of firing the already employed, protected by strong unions, but to create a new type of contract that once expired allows firms to costlessly lay off newly hired workers. The result of these reforms was the emergence of dual labor markets consisting of permanent workers that are difficult to hire and especially difficult to fire, and temporary workers, on probation for a fixed number of months, after which they are either promoted to be permanent or dismissed. Obviously, these reforms created a strong incentive for firms to hire more temporary workers; however, the fact that firms in these economies not only operate in imperfect labor markets, but also in imperfect capital markets further limited the creation of permanent jobs to the extent of firms' financial resources.

This paper shows that financial constraints restrict job creation even when labor markets are relatively flexible. While removing labor market rigidities helps firms to create jobs and to increase capital accumulation by releasing internal resources for investment, binding liquidity constraints hinder job creation. Using a dynamic model of labor demand under liquidity constraints, I evaluate the dynamics of capital, debt and labor under three counterfactual scenarios: (i) no temporary workers, (ii) elimination of firing costs, and (iii) elimination of financial constraints.

The first policy experiment reveals that the observed labor market reforms alleviated firms' liquidity constraints and that temporary labor did not substitute permanent labor, but labor altogether substituted capital. The second experiment shows that removing labor market rigidities would imply an initial substantial reduction in permanent labor with an increase in subsequent periods, but it would produce a modest increase in capital and a slow decrease in debt. By contrast, relaxing financial constraints would generate an important increase in capital accumulation, a sharp decrease in firms' debt and no mayor decline in permanent employment. Noticeably, the level of permanent labor produced by a relaxation of financial constraints would be considerably higher than the one produced by the sole elimination of labor market rigidities.

The 1990s have been a period of intensive theoretical and empirical research on the effect both of labor market rigidities and credit market frictions. The first literature is centered in explaining the effects of firing costs in labor demand, particularly in Western Europe (see, for example, Bentolila & Bertola (1990), Bentolila & Saint-Paul (1992), Hopenhayn & Rogerson (1993), Cabrales & Hopenhayn (1997) & Aguirregabiria & Alonso-Borrego (1999)). The effects of '*eurosclerosis*,' that is, labor markets with high firing costs, are ambiguous. In good times, sclerotic labor markets create fewer jobs than free labor markets; however, in bad times, sclerotic labor markets defend existing jobs better. The second literature focuses on the effects of credit market frictions on the real economy (see Bernanke, Gertler and Gilchrist (1999) for a survey). Under liquidity constraints the Modigliani and Miller (1958) proposition does not hold and firms' investment is limited by their internal collaterizable resources. In this environment, real and nominal shocks to the economy are magnified and last longer.

These literatures do not usually refer to each other: typically, the analysis of *eurosclerosis* abstracts from capital markets, whereas the analysis of capital market imperfections does not usually consider the labor market in a meaningful way. The present paper proposes a framework to analyze these two issues jointly.[1] It is a dynamic model where firms decide on a level of investment, permanent and temporary labor and debt subject to financial constraints, bankruptcy conditions and firing costs. The behavioral parameters of the theoretical model are estimated using its policy rules as an input in a maximum likelihood procedure. These parameters are used to perform the aforementioned policy experiments. The data come from the CBBE (Balance Sheet data from the Bank of Spain) and include financial variables as well as information on permanent and temporary employment.

Among Western European countries, Spain has been the country with the largest unemployment rate, almost 20% for more than a decade. In 1984 a labor reform attempted to counteract the sharp increase in unemployment suffered during the 'transition phase' to a free economy. This reform basically created temporary labor in Spain, so that after 1984 there was an important expansion of this type of contract. At the same time, it is well-documented that Spanish firms face significant financial constraints, so that financial variables have an important on firms' investment.(Alonso-Borrego and Bentolila 1994, Estrada and Vallés 1995) Therefore,

[1] There is a relatively recent and growing literature that focuses on the link between employment and credit market imperfections (Sharpe 1994, Nickel and Nicolitsas 1999, Acemoglu 2001, Wasmer and Weil 2002, Barlevy 2003). This literature, however, does not usually distinguish between temporary and permanent labor, which is crucial for the European case.

the Spanish economy illustrates well the kind of the imperfections faced by several European economies.

The remainder of the paper is organized as follows. The next section details the Spanish regulation wage setting and for and firing workers. Section 3 explains the model and characterizes the optimal solution. Section 4 describes the data and documents their basic trends. Section 5 discusses the maximum likelihood estimation procedure. Section 6 presents the results of the estimation, the behavioral parameters and an assessment of how well the model fits the data. Section 7 performs the three policy experiments mentioned above. The main conclusions of this paper are summarized in Section 8.

2 Institutional Background

In the 50s and the 70s several Western European governments used dismissal costs as a tool to discourage job destruction. However, in the 80s and 90s, confronted to persistently high unemployment rates, these governments reduced dismissal costs to some extent and created fixed-term contracts, producing thereby the uprising of dual labor markets. Spain is the country where temporary contracts are particularly important, and as such provides a good illustration on how these dual labor markets work.

In Spain, for declaring a so-called 'fair' dismissal a firm has to give a 3 month notice before firing a worker under a permanent contract and give a reason, which can be

- disciplinary or if the worker is found incompetent, in which case the worker can appeal and during the process he or she continues earning a salary;
- economic or technical, in which case in practice the firm has to justify that it had continuous losses for two years.

In this case, the worker receives 20 days of monthly wage per year worked, up to 12 monthly wages. If the worker goes to court and wins, the dismissal is declared 'unfair,' in which case the worker receives 45 days of monthly wage per year worked, up to 42 monthly wages. Only 15% of job terminations are settled in court, of which 73% are favorable to the workers.

Before 1984 fixed-term or temporary contracts in Spain were only 'causal,' that is, only applicable to seasonal jobs or to jobs replacing workers that were in maternity leave. In 1984 a reform broadened the scope of temporary contracts, so they became mostly 'noncausal.' In Spain, a temporary contract lasts at least six months and at most three years. After three years of being temporary, a worker has to be either promoted to sign a permanent contract or be fired. If the firm wants to terminate the contract before the contract length, the normal procedure applies, that is, there are high firing costs. Otherwise there is only a severance payment of 12 monthly wages per year worked. Courts are not involved in job termination under a temporary contract.

In Spain, unions play a crucial role in wage determination, as representation of trade unions is independent of membership. This means that union agreements affect almost the whole labor force. Moreover, by law only the most representative unions, two confederations, which receive public financing, are allowed to negotiate wages. There are practically no minority trade unions. The effect of this high degree of centralization and coordination is that wages negotiated by unions, are well above the minimum wage: the ratio average wages/minimum wages is 31.2%. In Portugal, with less centralization, the corresponding ratio is 42.6% (Bover, García-Perea and Portugal 2000). Thus, wages do not adjust to specific firms' circumstances; the negotiation of wage increases, closely related to the CPI, is centralized.

These two aspects of Spanish labor markets, high firing costs and wage rigidity, play a crucial role in the model described in the next section.

3 Model

I use a dynamic model where firms maximize the expected discounted value of their stream of dividends by choosing investment, debt, and two types of labor. It is a neoclassical model of investment on the lines of Jorgenson (1963), extended to include liquidity constraints and bankruptcy as in Pratap and Rendon (2003), as well as firing decisions.

3.1 Environment

The following features characterize the environment in which firms operate:

- Firms are wage-takers and wages are given, which is motivated by a fully elastic labor supply or regulated wages.

- There are two types of workers, with given productivities. Flexible or temporary workers are unskilled and rigid or permanent workers are skilled. The analysis abstracts from the promotion structure.[2]

- Credit market imperfections are assumed to be exogenous and characterized by a capacity constraint for issuing fresh equity.

3.2 The Firm's Problem

The firm operates in a stochastic environment where it chooses a sequence of investment I, rigid labor H, flexible labor L, and debt B to maximize the discounted stream of dividends D:

$$\sum_{t=0}^{\infty} \frac{E_t D_t}{(1+\rho)^t},$$

being ρ the discount rate, common for all firms.[3] Dividends are defined as

$$D = \theta K^{\alpha} \left(H^{\gamma} + \lambda L^{\gamma}\right)^{\frac{\beta}{\gamma}} - I - c^k(K, K') - c^h(H_{-1}, H) - w_H H - w_L L - (1+r)B + B',$$

that is, revenues from production which depend on capital K and on two types of labor, rigid labor H and flexible labor L, net of investment, adjustment costs of capital and of rigid labor, both labor costs, and net debt variation. The firm's risky environment is captured by a total factor productivity θ that follows a Markov process $P(\theta'|\theta)$ which is parameterized as an AR(1) process: $\ln\theta' \sim N\left(\mu + \phi \ln\theta, \sigma^2\right)$. The firm and the lenders observe this productivity before making investment, employment, and borrowing decisions. Production technology is contained in a Cobb-Douglas production function in capital and efficiency units of labor, with parameters α and β, respectively. Rigid and flexible labor are transformed into efficiency units of labor with a CES technology with parameters γ and λ. Investment involves an adjustment cost, parameterized as a quadratic function, and it is irreversible, that is, the firm

[2]The few analyses of the promotion structure from temporary to permanent employment in the literature made so far are based on the theory of efficiency wages (Güell 2000) or on human capital theory (Nagypál 2002). However, most of the research done so far simplifies the analysis by assuming two types of workers.

[3]In what follows, except in summations or in the likelihood funcion, variables in the current period will not carry a subscript, variables in the next period will be denoted by 'prime,' and variables in the past period will have the subscript -1.

can not decrease its capital level below its current undepreciated capital.

$$c^k(K, K') = \begin{cases} a\frac{I^2}{K}, \text{ if } I \geq 0, \text{ and} \\ \infty, \text{ if } I < 0; \end{cases}$$

where $I = K' - (1 - \delta_k) K$, and δ_k is the depreciation rate of capital. Wage rates of rigid and flexible labor are w_H and w_L, respectively. The firm can adjust flexible labor and increase permanent labor at no cost, but it has to incur in firing costs in order to reduce rigid labor:

$$c^h(H_{-1}, H) = \chi_f F \left[(1 - \delta_h) H_{-1} - H \right]$$

where $\chi_f = 1$, if $(1 - \delta_h) H_{-1} > H$, zero, otherwise, and F is the firing cost in terms of unit variations in rigid labor. Workers quit their jobs at an exogenous rate δ_h without producing any cost for firms. Hiring and inaction in firing does not entail any cost of adjustment. While the firing cost captures the labor market imperfection, the capital market imperfection consists in that the firm has a capacity constraint for issuing fresh equity. In the context of the model, this implies that there is a lower bound on dividends:

$$D \geq \overline{D}. \tag{1}$$

In the current period the firm pays debt B at interest rate r, determined both in the past period, and contracts next period's debt B' at interest rate r'. The firm does not lend money in any way, that is, it is constrained to have a nonnegative level of debt:

$$B' \geq 0. \tag{2}$$

The timing of events are the following: (i) the firm enters the period with a level of capital K and a level of debt B contracted in the past period at the interest rate r; and because there are adjustment costs to rigid labor, the firm needs to keep track of the level of rigid labor in the previous period H_{-1}; (ii) productivity θ is realized; the firm stays in business if its value is at least the value of an outside option, and exits otherwise; (iii) the surviving firm chooses investment, new debt and the two types of labor.

Consequently, the value of the firm is determined by the following Bellman equation:

$$
\begin{aligned}
V\left(K,H_{-1},(1+r)\,B,\theta\right) \;=\; & \max_{K',H,L,B'}\Big\{\theta K^{\alpha}\left(H^{\gamma}+\lambda L^{\gamma}\right)^{\frac{\beta}{\gamma}}+\left(1-\delta_k\right)K-K'-c^{k}(K,K') \\
& -c^{h}(H_{-1},H)-w_H H-w_L L-(1+r)B+B' \\
& +\frac{1}{1+\rho}E\max\left[V(K',H,(1+r')\,B',\theta'),\Omega\left(\theta'\right)\right]\Big\} \\
& \text{subject to (1), and (2),}
\end{aligned}
$$

where $\Omega(\theta)$ represents the value of the outside option, defined as the value of starting a firm at the same idiosyncratic productivity, but with no net resources: no capital, no commitment to permanent workers, and no debt, that is, $\Omega(\theta) = V(0,0,0,\theta)$. In this environment, the value of the firm is increasing in capital and productivity, decreasing in total debt payments and it is ambiguous in lagged rigid labor, i. e., $V_K > 0, V_{H_{-1}} \leq 0, V_{(1+r)B} < 0, V_\theta > 0$. Let the lowest productivity that leaves the firm in business be

$$
\underline{\theta}\left(K,H_{-1},(1+r)\,B\right) \equiv \left\{\theta\,|V\left(K,H_{-1},(1+r)\,B,\theta\right)=\Omega\left(\theta\right)\right\};
$$

then, the exit rule is:

$$
\begin{aligned}
\text{if } \theta &\geq \underline{\theta}, && \text{the firm stays in business;} \\
\text{if } \theta &< \underline{\theta} && \text{the firm exits the market / goes bankrupt.}
\end{aligned}
$$

Hence, the probability of survival next period is $\Pr(\theta' > \underline{\theta}'|\theta) = 1-\Phi(\kappa')$, where $\kappa' = \frac{\ln\underline{\theta}'-\gamma\ln\theta-\mu}{\sigma}$ and $\Phi(.)$ is the normal cumulative distribution function. By the implicit function theorem applied to the definition of $\underline{\theta}$, we obtain the following derivatives: $\underline{\theta}_{K'} < 0$; $\underline{\theta}'_H \geq 0$; $\underline{\theta}'_{(1+r')B'} > 0$;which imply that the survival probability increases in capital and decreases in rigid labor, debt and the interest rate.

A firm that exits the industry or goes bankrupt at time t_s defaults on its debt. It does not produce in that period and shuts down forever, so that $K_t = H_t = L_t = B_t = 0$ at, $t > t_s$. In that event, undepreciated capital covers firing and bankruptcy costs and does not go to the lender or the firm.

Firms and lenders establish a firm-specific debt contract so that lenders earn zero expected profits. Assuming that competitive lenders face an elastic supply of funds at the risk free rate ρ, the interest rate r' charged on debt B' is determined by the condition:

$$G(r') = [1 - \Phi(\kappa')](1 + r') B' - (1 + \rho) B' = 0,$$

The first term represents the expected return to the lender, that is, the probability of survival times the return on borrowing; the second term is the opportunity cost of the funds. This equation pins down the firm-specific interest rate as a supply function:

$$r'\left(K', H, B', \theta\right) = \left\{ r' \middle| G(r') = 0 \right\}. \tag{3}$$

Using the implicit function theorem in this equation, one can determine that the interest rate is decreasing in capital, increasing in debt, and ambiguous in rigid labor; more precisely, $r'_{K'} < 0$, $r'_{B'} > 0$, $r'_H \geq 0$, $r'_\theta < 0$. The interest rate ranges between ρ, if its survival were guaranteed, and infinity, if it goes bankrupt next period with certainty (in which case lenders will not lend to that firm, so that a Ponzi scheme is ruled out). The interested reader will find more details on this in Appendix A1.

3.3 Optimal Policy

To solve this problem, I form the Lagrange equation, which becomes the new maximand:

$$\begin{aligned} Z(K', H, L, B') &= (1 + y_D) D - y_D \overline{D} + y_B B' \\ &\quad + \frac{1}{1+\rho} \int \max\left[V(K', H, (1 + r') B', \theta'), \Omega(\theta)\right] dP(\theta'|\theta). \end{aligned}$$

The first order conditions for this problem are then

$$\begin{aligned} Q_{K'} &\equiv \frac{1}{1 + 2a\frac{I}{K}} \widetilde{E}(1 + y'_D)\left(\alpha\theta' K'^{\alpha-1}\left(H'^{\gamma} + \lambda L'^{\gamma}\right)^{\frac{\beta}{\gamma}} + 2a(1 - \delta_k)\frac{I'}{K'} + a\frac{I'^2}{K'^2} - r'_{K'}B'\right) \\ &= (1 + y_D)(1 + \rho), \\ Q_H &\equiv \frac{\widetilde{E}(1 + y'_D)\left(\chi_f F(1 - \delta_h) + r'_H B'\right)}{\beta\theta K^{\alpha}\left(H^{\gamma} + \lambda L^{\gamma}\right)^{\frac{\beta}{\gamma}-1} H^{\gamma-1} - w_H + \chi_f F} = (1 + y_D)(1 + \rho), \\ Q_{B'} &\equiv (1 + r' + r'_{B'}B')\,\widetilde{E}(1 + y'_D) = (1 + y_D + y_B)(1 + \rho), \\ w_L &= \beta\lambda\theta K^{\alpha}\left(H^{\gamma} + \lambda L^{\gamma}\right)^{\frac{\beta}{\gamma}-1} L^{\gamma-1}, \end{aligned}$$

where $\widetilde{E}X = \int_{\theta' \geq \underline{\theta}'} XdP(\theta'|\theta)$. Using these conditions and the constraints we can simplify the solution of the four choice variables, plus the two Lagrange multipliers, to only two variables: capital and rigid labor. Since the first order condition for flexible labor is static, that is, it depends on current capital and productivity, then

$$L(K,H,\theta) = \left\{ L \left| \beta\lambda\theta K^{\alpha}\left(H^{\gamma}+\lambda L^{\gamma}\right)^{\frac{\beta}{\gamma}-1} L^{\gamma-1} - w_L = 0 \right. \right\}. \tag{4}$$

Moreover, one can show that productivity and capital increase flexible labor, whereas rigid workers can be complements or substitutes of flexible workers, that is.$L_{\theta} > 0$, $L_K > 0$, and

$$L_H \begin{cases} > 0 \text{ if } \gamma < \beta, \\ = 0, \text{ if } \gamma = \beta, \\ < 0, \text{ if } \gamma > \beta. \end{cases}$$

On the other hand, one can also show that a firm contracts debt only after exhausting its capacity to issue equity:

Proposition 1 *A firm cannot simultaneously incur in debt and issue positive dividends, that is, it cannot be the case that $y_B = 0$ and $y_D = 0$. Proof: In Appendix B.1.*

That is, when debt is positive, the dividend constraint is binding, which gives rise to three possible regimes:

Regime I: $y_{B'} = 0$, $y_D > 0$, or $B' > 0$, $D = \overline{D}$;

Regime II: $y_{B'} > 0$, $y_D > 0$, or $B' = 0$, $D = \overline{D}$;

Regime III: $y_{B'} > 0$, $y_D = 0$, or $B' = 0$, $D > \overline{D}$.

This means that debt has to be

$$B' = \max\left(K' + c^k(K,K') + c^h(H_{-1},H) + (1+r)B - \pi(H) - \overline{D}, 0\right) \tag{5}$$

where $\pi(H) = \theta K^{\alpha}\left(H^{\gamma}+\lambda L^{\gamma}\right)^{\frac{\beta}{\gamma}} + (1-\delta_k)K - w_H H - w_L L$. This rule determines debt as a function of capital next period and rigid labor.

Therefore, the solution is reduced to solving two equations for two variables. Since both the adjustment cost functions of capital and rigid labor have discontinuous derivatives, the policy rules for capital and labor are characterized by their adjustment and by the binding constraints in dividends and debt. Let $Q_H^C = Q|_{\chi_f=0}$ and $Q_H^F = Q_H|_{\chi_f=1}$, then there will be two solutions, one with hiring and one with firing:

$$(K'^*, H^*)_j = \{(K', H)\,|$$

$$\begin{array}{rl} \text{Eq. I} : & \left\{ \begin{array}{l} Q_{K'} = Q_H^j \text{ (investment), if } c^k(K,K') < \infty, \text{ or} \\ K' = (1-\delta_k)\,K \text{ (no investment), otherwise;} \end{array} \right. \\ \text{Eq. II} : & \left\{ \begin{array}{l} Q_H^j = F_{B'}, \text{ Regime I} \\ K' + c^k(K,K') = \pi\,(H) - c^h(H_{-1},H) - (1+r)\,B - \overline{D}, \text{ Regime II.} \\ Q_H^j = 1+\rho, \text{ Regime III} \end{array} \right. \\ & \} \end{array}$$

where $j = C$, if $\chi_f = 0$, and $j = F$, if $\chi_f = 1$. If there is no hiring and firing, a solution will be attained at

$$(K'^*, H^*)_S = \{(K', H)\,|$$

$$\begin{array}{rl} \text{Eq. I} : & H = (1-\delta_h)\,H_{-1}, \\ \text{Eq. II} : & \left\{ \begin{array}{l} \left\{ \begin{array}{l} Q_{K'} = Q_{B'}, \text{ Regime I} \\ K' + c^k(K,K') = \pi\,(H) - c^h(H_{-1},H) - (1+r)\,B - \overline{D}, \text{ Regime II.} \\ Q_{K'} = 1+\rho, \text{ Regime III} \end{array} \right. \\ \text{(investment) if } c^k(K,K') < \infty, \\ K' = (1-\delta_k)\,K \text{ (no investment), otherwise.} \end{array} \right. \\ & \}. \end{array}$$

And the solution will be selected in the following way:

$$(K'^*, H^*) = \left\{ \begin{array}{l} (K'^*, H^*)_C\,, \text{ if } H_C \geq (1-\delta_h)\,H_{-1}, \\ (K'^*, H^*)_F\,, \text{ if } H_F < (1-\delta_h)\,H_{-1}, \text{ and} \\ (K'^*, H^*)_S\,, \text{ if } H_C < (1-\delta_h)\,H_{-1} \leq H_F. \end{array} \right.$$

Once the solution is found, one can determine the Lagrange multipliers:

$$y_D = \max\left(\frac{Q_{K'}}{1+\rho} - 1, 0\right);\; y_B = \max\left(\frac{Q_{B'} - Q_{K'}}{1+\rho}, 0\right).$$

Let the pairs $\left(K^I, H^I\right)$ and $\left(K^{III}, H^{III}\right)$ be the optimal solutions for capital and rigid labor in Regime I and Regime III, respectively. In Regime I, with a binding dividend constraint, all state variables determine the solution, thus:

$$(K, H)^I \equiv (K, H)^I \left(K, H_{-1}, (1 + r) B, \theta\right),$$

And given that in Regime III the dividend constraint does not bind, only capital and lagged rigid labor through the adjustment costs and current productivity determine the optimal solution:

$$(K, H)^{III} \equiv (K, H)^{III} \left(K, H_{-1}, \theta\right)$$

Figure 1a illustrates the optimal solution for H as a function of H_{-1}. In models of adjustment costs under free capital markets, firms with a level of rigid labor lower than H_C adjust to H_C, whereas firms with a level of rigid labor higher than H_F adjust to H_F. However, under financial constraints firms that are financially poor may not afford to pay the adjustment cost. This implies that firms that want to hire workers only hire to a level below H_C, and firms that want to fire workers can only reduce their rigid labor to a level above H_F. Entering the period with too few or too many rigid workers is a liability for the firm as it has to pay firing costs, respectively, to reach its optimal level of rigid workers. These costs thus create persistence in the number of rigid workers and link this number with the financial position of the firm: a lack or an excess of rigid workers are both a sign that the firm's net worth is low.

3.4 Sequential Solution

Having characterized the optimal solution, for computational purposes it is convenient to rewrite the problem as a sequential maximization in two stages and exploit the connections between choice variables found above.

Stage I: Solution for capital and debt conditional on rigid labor.

Conditioning on rigid labor, we maximize the value function over capital, which determines debt B' by Eq. (**??**) and the interest rate next period r' by Eq. (3). The value function conditional on rigid labor H is then:

$$W\left(x, K, \theta; H\right) = \max_{K'} \left\{ \max\left(x - K' - c^k\left(K, K'\right), \overline{D}\right) + \frac{1}{1+\rho} E \max\left[V(K', H, \left(1+r'\right) B', \theta'), \Omega\left(\theta'\right)\right.\right.$$

where

$$x = \theta K^{\alpha}\left(H^{\gamma} + \lambda L^{\gamma}\right)^{\frac{\beta}{\gamma}} + (1-\delta)K - w_H H - c(H_{-1}, H) - w_L L - (1+r)B. \qquad (6)$$

In this maximization there is no need for Lagrange multipliers, because Eq. (**??**), implying that current dividends are $\max\left(x - K' - c^k\left(K, K'\right), \overline{D}\right)$, takes care of the dividend and the debt constraints. The solution to this problem is contained in the policy rule $K^w\left(x, K, \theta; H\right)$. Optimal debt is obtained from this solution and Eq. (**??**).

Stage II: Solution for rigid labor

Using Eq. (**??**) and Eq. (6) we map the state variables $\left(K, H_{-1}, \left(1+r\right)B, \theta\right)$ and rigid labor H to internal resources and maximize the function found in the previous stage over rigid labor:

$$V\left(K, H_{-1}, \left(1+r\right)B, \theta\right) = \max_{H} W\left(x, K, \theta; H\right).$$

The corresponding solution is the policy rule $H^* \equiv H\left(K, H_{-1}, \left(1+r\right)B, \theta\right)$, which determines

$L^* \equiv L^*\left(K, H_{-1}, \left(1+r\right)B, \theta\right) = L(K, H^*, \theta)$, optimal flexible labor, from Eq. (**??**);

x^*, defined as internal resources at the optimum, from Eq. (6);

$K^* \equiv K^*\left(K, H_{-1}, \left(1+r\right)B, \theta\right) = K^w\left(x, K, \theta; H\right)$, optimal capital next period, from mapping optimal rigid labor to the solution of the previous stage;

$B^* \equiv B^*\left(K, H_{-1}, \left(1+r\right)B, \theta\right) = \max\left(K^* - c^k\left(K, K^*\right) - x^* + \overline{D}, 0\right)$, optimal debt next period, from Eq. (**??**).

Since this model does not admit an analytical solution, the solution has to be approximated by numerical methods. I compute a numerical solution for assigned parameter values by discretizing the state space, that is, all possible combinations of K, H, and $(1+r)B$, into a grid of points. This procedure is explained in greater detail in Appendix A2. Notice that Eqs (??) and (??) are used to solve for two instead of four choice variables and that the sequential solution is faster than a simultaneous one.[4]

4 Data

The data come from balance sheet records kept at the Bank of Spain (Central de Balances del Banco de España - CBBE). This dataset contains 94192 observations for more than 200 variables about the financial structure as well as employment of 19473 firms from 1983 until 1996. I conducted a selection of the data, leaving in the sample manufacturing private firms that do not change activity, do not merge or split and have more than five consecutive observations. I also excluded firms with observations that have negative or zero gross capital formation. The final sample consists of 1217 firms with 10787 observations. The employment information is given in terms of permanent and temporary workers, which correspond to the categories of rigid and permanent labor, respectively. A further description of the selection of the data, the definition of the variables and the structure of the panel is provided in Appendix A3.

[Insert Table 1 here]

Table 1 presents descriptive statistics for the main variables in original amounts, ratios and variations. The data for capital and debt are given in millions of pesetas of 1987, computed using the industrial price index. This table gives an idea about the values of the variables by size, measured as thirds in the distribution of capital, and by period: before the labor market reform (1983-1984), up to five years after the reform (1984-1989), and 1990-1996. This period is characterized by an important growth of capital, 3.3% by year, being the growth rate higher between 1985 and 1989, and a decline of debt. Notice that in relative terms debt by worker is higher for the medium sized firms, whereas the debt-capital ratio is monotonically decreasing in firms' size. As predicted by the model, firms with a high level of capital rely less on debt for their financial needs than small firms, which may be thirsty for financial resources.

[4] To simplify the argument assume that all loops executed in the numerical solution have the same size N, an integer. Then, the sequential maximization (four states and one choice plus four states and one choice) is clearly faster is than the simultaneous one (four states and two choices), as $N^5 + N^5 < N^6$, if $N > 2$.

In this same period, flexible labor substitutes rigid labor, and, moreover, experiences a very high expansion, which is responsible for most of the expansion in total labor in the eighties and nineties. It is noteworthy that after 1984 small and large firms have a lower percentage of flexible labor over the total labor force than medium sized firms. According to the theoretical model, firms with little capital demand relatively less of either type of labor, while firms with large capital levels can afford to pay the labor adjustment costs and hire more rigid labor. Graphical evidence and further discussion of these trends is provided in Section 6, which compares actual and predicted paths of all these variables.

5 Estimation

The estimation consists of using the policy rules of the theoretical model as an input in a maximum likelihood estimation. In the next subsections I explain the way that the estimation procedure accounts for the introduction of flexible labor in 1984, the construction of the likelihood contributions, and the likelihood function maximization.

5.1 The 1984 Labor Market Reform

Because the sample starts in 1983 and ends in 1996, it covers two regimes: one with and one without flexible labor. In the estimation procedure, this is accounted for as an unanticipated regime change, so that

$$\begin{aligned} \text{Regime wihout flexible labor} &: \quad t = 1983, 1984, \\ \text{Regime with flexible labor} &: \quad t \geq 1985. \end{aligned}$$

I solve the dynamic programming problem two times, one for each regime: policy rules that match data up to 1984 exclude flexible labor as a choice; policy rules that match data after 1984 do include flexible labor as a choice.

5.2 Likelihood function

The log-likelihood function is the sum of the log of each firm's joint density of the sequence of observed capital, rigid and flexible labor, and debt, conditional on the first observation of capital and debt:

$$\ln \mathcal{L}\left(\Theta | K_1^{obs}, B_1^{obs}\right) = \sum_{i=1}^{N}\sum_{t=1}^{T_i} \ln \mathcal{L}_{it}, \tag{7}$$

where $\mathcal{L}_{it}$ is the likelihood contribution of firm i at time t and Θ is the parameter set. The estimated parameter set is defined as

$$\widehat{\Theta} = \arg\max \ln \mathcal{L}\left(\Theta | K_1^{obs}, B_1^{obs}\right)$$

If the random process for productivity in the theoretical model accounts for all observed variables, the construction of the individual period-specific likelihood contributions is straightforward. In that case, the likelihood contribution for period t (dropping individual subscripts to improve legibility) is

$$\mathcal{L}_t = \widehat{\psi}_t \frac{1}{\sigma}\phi\left(\frac{\ln\theta_t - \gamma\ln\theta_{t-1} - \mu}{\sigma}\right), \, t = 1, ..., T_i,$$

where $\widehat{\psi}_{it} = 1$, if the model predicted variables coincide with the observables, and $\widehat{\psi}_{it} = 0$, otherwise. Three cases are possible

Initial period, $t = 1$**:** Since the first observations of capital and debt are not predicted by the model, as in other panel data estimations, it is assumed that $K_1 = K_1^{obs}$ and $B_1 = B_1^{obs}$. For $\widehat{\psi}_t$ to be one, observables K_2^{obs}, B_2^{obs}, H_1^{obs}, and L_1^{obs} have to be produced by the state variables K_1, H_0, $(1 + r_1) B_1$, θ_1. However, we do not observe θ_1, H_0 and r_1. Because we can recover the interest rate from the function $r_1 (K_1, H_0, B_1, \theta_0)$, we need to find the values of H_0, θ_0, and θ_1 that yield the observables. Finding these values means also determining the interest rate $r_2 (K_2, H_1, B_2, \theta_1)$ at which the firm contracts debt B_2^{obs}.

Intermediate periods, $t = 2, ..., T - 1$**:** Once we know the values of K_t, H_{t-1}, B_t, r_t, we just need to find the productivity θ_t that yields K_{t+1}^{obs}, B_{t+1}^{obs}, H_t^{obs}, L_t^{obs}. This productivity also gives us $r_{t+1} (K_t, H_{t-1}, B_t, \theta_t)$.

Last period, $t = T$**:** At the last period, we only need to account for the last observations of labor. Therefore, we only need to find θ_T such that $H_T^{obs} = H_T (K_T, H_{T-1}, (1 + r_T) B_T, \theta_T)$, and $L_T^{obs} = L_T (K_T, H_{T-1}, (1 + r_T) B_T, \theta_T)$.

In the construction of the likelihood contributions, besides accounting for all observables (except for the first observation of capital and debt), we obtain rigid labor H_0 and the sequence of unobservable productivities $\{\theta_t\}_{t=0}^{T}$.

A general way of expressing the construction of $\widehat{\psi}_t$ is

$$\widehat{\psi}_t = \begin{cases} \max_{H_0,\theta_0,\theta_1} \psi_t, & \text{if } t=1, \text{ and} \\ \max_{\theta_t} \psi_t, & \text{if } t=2,...,T, \end{cases}$$

where

$$\psi_t = \begin{cases} g\left(H_t^{obs}-H_t\right) g\left(L_t^{obs}-L_t\right) g\left(K_{t+1}^{obs}-K_{t+1}\right) g\left(B_{t+1}^{obs}-B_{t+1}\right), \text{ if } t=1,..T-1, \text{ and} \\ g\left(H_t^{obs}-H_t\right) g\left(L_t^{obs}-L_t\right), \text{ if } t=T. \end{cases}$$

A strict condition for the likelihood function not to become zero is that $\widehat{\psi}_t = 1$, for all $t = 1, 2, ..., T$, which implies that $g\left(Y_t^{obs}-Y_t\right) = 1\left(Y_t^{obs}-Y_t=0\right)$, $Y = K, B, H, L$. However, with only one source of randomness in the model it is unlikely that the likelihood function does not collapse. Even if the data were generated by the theoretical model, initial parameters would not account for the sequence of observables. The solutions proposed in the literature consist in adding extra sources of randomness, typically measurement errors, which are introduced in the likelihood computation, not in the theoretical model (Flinn and Heckman 1982, Wolpin 1987), or extra random variables in the theoretical model, such as choice-specific shocks, usually following an extreme-value distribution (Rust 1988).

The solution proposed here is to replace the requirement of choosing the unobserved productivities that produce zero distance between observed and predicted variables by a milder requirement: choosing the unobserved productivities that minimize the distance between the observed variables and the variables predicted by the dynamic programming model. This way, whenever the observed variables do not coincide with their predicted levels, the likelihood value does not become zero but shrinks by a value that is proportional to the distance between the predicted variables and their observable counterparts. Since minimizing the distance at each iteration is equivalent to maximizing the likelihood of occurrence at each observation, let

$$g\left(Y_t^{obs}-Y_t\right) = \frac{1}{\sigma_Y}\phi\left(\frac{Y_t^{obs}-Y_t}{\sigma_Y}\right),$$

where σ_Y for $Y = K, B, H, L$ measures the distance between observed and predicted variables. Thus, this procedure is basically a smoothed version of the estimation without any additional source of randomness in the theoretical model. It does not collapse and allows to recover a sequence of predicted variables, observables and unobservables:$\{K_t\}_{t=1}^{T+1}$, $\{B_t\}_{t=1}^{T+1}$, $\{H_t\}_{t=0}^{T}$, $\{L_t\}_{t=1}^{T}$, and $\{\theta_t\}_{t=0}^{T}$. Any analysis of counterfactual outcomes can use the sequence of productivities to generate alternative sequences of observables. Moreover, if the model is well specified, maximization of the likelihood function should produce a perfect prediction of the observables by the model, that is, σ_Y measure misspecification.

The set of parameters to be estimated is $\Theta = \{\alpha, \beta, \delta, \gamma, \lambda, \rho, w_H, w_L, F, a, \phi, \mu, \sigma, \overline{D}, \sigma_K, \sigma_H, \sigma_L, \sigma_B\}$, that is, the behavioral parameters and the standard deviations of the predicted errors. For the computation of this likelihood function, I exploit the discretization of the variables performed to solve the theoretical model (see Appendix A4). The likelihood function is maximized using the Powell algorithm (Press et al. 1992) which uses direction set methods to find the maximum. This algorithm relies on function evaluations, not gradient methods.

6 Results

6.1 Parameters

Table 2 reports the maximum likelihood parameter estimates and the corresponding asymptotic standard errors. The capital coefficient is estimated at around 0.26, whereas the labor coefficient is around 0.67. These Cobb-Douglas parameters display decreasing returns to scale. The value of 0.89 for γ indicates sustitutability between the two types of labor, as indicates $\gamma > \beta$. The estimate for λ is around 0.25, that is, flexible labor is around 25% as productive rigid labor.

[Insert Table 2 here]

The depreciation parameter for capital of around 0.16 in both specifications is in line with previous research, whereas the rate of quits of rigid labor is 0.01. Variations in rigid labor do not rely on quits, but on the firms' decisions. Wage rates of 2.0581 for rigid labor and of 0.6589 for flexible labor correspond respectively to average and minimum wages per annum in Spain. The risk-free interest rate estimated at 5.19% per annum coincides with the observed one during the sample period. Firing costs are estimated to be 2.4116, which exceed the annual wage. These firing costs cannot be interpreted just as the observed severance payments, but as all possible costs associated with the process of firing a workers. For example, the worker may appeal the firm's decision to fire him or her, in which case the firing costs are not only much higher than the severance payments, but the worker would also continuing working for the firm.

The autocorrelation parameter of the productivity process is 0.89. The lower threshold on dividends is estimated at around 14. Capital adjustment costs are also substantial: 1.8420, which means that the firm has an important incentive for inaction in investment. The standard deviation of the predicted errors are low compared to the standard deviation of the four variables explained in the descriptive section; they also coincide roughly with the implied sample standard deviations.

6.2 Graphical Comparison

Figure 2 reports the paths for actual and predicted average capital, debt, and rigid and flexible labor by year. The model displays good replication of the data, especially of capital and permanent labor. The predicted path for debt fluctuates around the actual one, with some overprediction in some years. This looks clearer in Figure 2c, which shows the debt-capital ratio over time. There is an increase in this ratio from 1983 until 1985 and from then onwards a decrease. Predicted flexible labor in the first two years is zero, because in these years the model does not admit flexible labor as a choice. In the years thereafter predicted flexible labor grows relatively faster than the actual one and the gap between this actual and predicted variable narrows down. This trend is also clear in Figure 2d showing the actual and predicted percentage of temporary labor over the total labor force. These graphs are illustrative on the success of the model in replicating the data; a more accurate assessment is provided in the following subsection.

[Insert Figure 2 here]

6.3 Goodness of Fit

To assess if the parameter estimates capture the essential features of the data, I compare the observed and the predicted choice distributions of capital, debt and the two types of labor. I perform goodness of fit tests to evaluate if the distribution of the data can be produced by the theoretical model at the estimated parameters. The test statistic across choices j at time t is defined as $\chi_t^2 = \Sigma_{j=1}^{J} \frac{(n_{jt} - \hat{n}_{jt})^2}{\hat{n}_{jt}}$, where n_{jt} is the actual number of observations of choice j at time t, $\hat{n}_{jt}$ be the model predicted counterpart, J is the total number of possible choices and T is the number of years. This statistic has an asymptotic χ^2 distribution with $J - 1$ degrees of freedom. To construct this statistic, I divide capital stock, debt and the two types of labor into five quintiles each, that is, $J = 5$.

Additionally, I report the R^2 statistic defined as

$$R^2 = \frac{\sum \widehat{Y}^2}{\sum \widehat{Y}^2 + \sum e^2},$$

where $\widehat{Y}$ is the predicted variable (capital, debt, and the two types of labor) and $e = Y_{obs} - \widehat{Y}$ is the predicted errors. [5]

[Insert Table 3a and Table 3b here]

Table 3a and Table 3b reports the actual and predicted averages, the χ_t^2 and R^2 statistics by variable and by year. The average and predicted variables were used to construct the graphs discussed in he previous subsection. The χ_t^2 statistic of capital and debt for the first year are zero because the model predicted distribution is generated using the first observation on capital and debt in the data. As in the graphical comparison, the model fit for capital, debt, and rigid labor is good. For flexible labor, in spite of the systematic average underprediction of the model, the χ^2 statistic is significant for all years. The R^2 statistic shows the same figure: while capital and rigid labor exhibit an R^2 statistic above 0.95, this statistic is above 0.73 for debt and 0.4 for flexible labor.

I also report the sample standard deviations of the predicted errors of each variable in the last row of each table. Notice that they are very close to those estimated in the maximum likelihood procedure: σ_K, σ_H, σ_L, σ_B.

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[5] Unlike in the linear regression framework, this $\sum Y_{obs}^2 \neq \sum \widehat{Y}^2 + \sum e^2$. Squaring and summing across observations, one obtains $\sum Y_{obs}^2 = \sum \widehat{Y}^2 + 2 \sum \widehat{Y} e + \sum e^2$, and it is not necessarily true that $\sum \widehat{Y} e = 0$.

7 Regime Changes

Having recovered the underlying parameters of the model and assessed its success in replicating the data, I perform some regime changes. Starting off with the true values 1983 and 1984 and simulate the paths of the four variables under three counterfactual scenarios from 1985 onwards: (i) there is no labor reform in 1984, that is, there is no flexible labor throughout the sample period; (ii) the reform in 1984 consists in removing labor rigidities fully; and (iii) the reform in 1984 consists in relaxing liquidity constraints. These experiments are useful to quantify the contribution of flexible contracts, labor market rigidities and liquidity constraints in explaining the observed trends in the data.

To build these counterfactual scenarios I use the sequence of predicted productivity levels and the predicted observables in 1983 and 1984. From 1985 onwards I use the policy rules that solve the theoretical model evaluated at parameter set that corresponds to the new regime. The sequences of new predictions are reported in Table 4 and depicted in Figure d.

[Insert Table 4a, Table 4b and Figure 3 here]

7.1 No Flexible Labor

Figure 3a and Figure 3b graph the actual and predicted paths of the four variables, if there had been not labor reform in 1984. The numerical values are presented in the second column of Table 4 for each variable, corresponding to the sequence under liquidity constraints, labor market rigidities and no flexible labor. It is clear that the observed reform did not provoke any dramatic change in any observed variable, except in debt and flexible labor. Had the 1984 labor reform not occurred, in the following years capital and debt levels would have been higher on average and rigid labor would have been lower on average. This indicates that the labor market reform (i) produced substitution from capital to labor, (ii) alleviated liquidity constraints, reducing firms' debt, and (iii) did not variate rigid labor substantially.

7.2 No Hiring and Firing Costs

Figure 3c and Figure 3d depict the paths of the variables if labor rigidities had been fully removed. This experiment consists in solving the dynamic programming problem using the estimated parameters, except the firing costs which are set to zero: $F = 0$. Removing labor market rigidities would (i) produce a substantial decrease in rigid labor just immediately after the regime change, with a recovery in the years thereafter, (ii) increse flexible labor substantially, (iii) have no substantial effect on debt, and (iv) produce a slight increase in capital. This reaction is a sign that firms have too much rigid labor, which they would like to get rid of but cannot because of the high costs that this would represent.

7.3 Free Capital Markets

In the next experiment I assess the effect of relaxing the dividend constraint. This is accomplished setting $\overline{D}$ at a very high absolute value. As shown in Figure 3e and Figure 3f, this regime change implies (i) a substantial increase in capital accumulation, (ii) a minor reduction followed by a further increase in rigid labor, and (iii) a substantial reduction in debt. This regime change is indicative of the potential for increasing investment in the European economy and shows that removing financial constraints creates more employment than only removing labor market rigidities. Actually, once financial constraints are relaxed, removing firing costs does not produce different trajectories of the four relevant variables. *Eurosclerosis* can persist under imperfect capital markets, but a financial liberalization can activate both the sclerotic labor markets as well as increase investment by a big amount.

8 Conclusions

Using a dynamic model of labor demand under liquidity constraints, I have shown that Spanish firms use flexible contracts to alleviate financial constraints, reducing thereby their level of borrowing. Since creation of permanent jobs is limited by owned financial resources, firms have to improve their financial position to be able to hire more permanent workers, reduce their demand for flexible ones and their need for debt.

A reform that removes labor market rigidities, politically unfeasible in most Western European economies, would allow firms to get rid of unnecessary permanent employment, but it would produce a modest increase in investment and a slow reduction of debt. On the contrary, relaxing financial constraints would produce similar results as in the previous reform, just at a higher level: it would create more permanent employment and produce a big jump in firms' investment as well as a big reduction in borrowing. Policies designed to increase job creation cannot abstract from financial variables and investment and be confined to labor market policy measures; they should also be oriented toward relaxing financial constraints.

Appendix

A1. Model

Properties of the exit rule.- Using the implicit function theorem one can establish:

$$\underline{\theta}_{K'} = -\frac{V_{K'}}{\Delta V'_{\theta}} < 0; \qquad \underline{\theta}'_{(1+r')B'} = -\frac{V_{(1+r')B'}}{\Delta V'_{\theta}} > 0; \qquad \underline{\theta}'_{H} = -\frac{V_{H}}{\Delta V'_{\theta}} \lesseqgtr 0;$$

where

$$\begin{aligned} V_{K'} &= \left(1+y'_D\right)\left[\alpha K'^{\alpha-1}\theta'\left(H'^{\gamma}+\lambda L'^{\gamma}\right)^{\frac{\beta}{\gamma}}+1-\delta_k+2a\left(1-\delta_k\right)\frac{I}{K}+\frac{I^2}{K^2}\right] > 0 \\ V_{(1+r')B'} &= -\left(1+y'_D\right) < 0 \\ V_H &= -\left(1+y'_D\right)\chi_f F\left(1-\delta_h\right) \leq 0 \end{aligned}$$

The denominator $\Delta V'_{\theta} = V'_{\theta} - \Omega'_{\theta}$ is positive, because $V_{K\theta} = (1+y_D)\,\alpha K^{\alpha-1}\left(H^{\gamma}+\lambda L^{\gamma}\right)^{\frac{\beta}{\gamma}} > 0$ and $V_{\theta H} = V_{\theta(1+r)B'} = 0$.

Endogenous interest rate.- The interest rate solves $G(r') = [1-\Phi(\kappa')](1+r')B' - (1+\rho)B' = 0$, which may not yield a unique solution for r' given K', B' and θ as it is not monotonically increasing in r':

$$G_{r'} = \left[1-\Phi\left(\kappa'\right)\right]B' - \frac{1}{\sigma}\phi\left(\kappa'\right)\left(1+r'\right)\frac{\underline{\theta}'_{r'}}{\underline{\theta}'}B'$$

where $\kappa' = \frac{1}{\sigma}\left(\ln\underline{\theta}\prime - \phi\ln\theta\right)$.

When there are multiple solutions, competition between lenders will lead to the lowest of these rates. Since $G(\rho) = -\Phi(\kappa')(1+\rho)B' < 0$, if at least one equilibrium rate exists, there is a low value of r', such that $G_{r'} > 0$. Using the implicit function G we obtain the derivatives of the interest rate function over its arguments shown in the main text: $r'_{K'} = \Upsilon\frac{\underline{\theta}'_{K'}}{\underline{\theta}'} < 0$, $r'_{B'} = \Upsilon\frac{\underline{\theta}'_{B'}}{\underline{\theta}'} > 0$, $r'_{H} = \Upsilon\frac{\underline{\theta}'_{H}}{\underline{\theta}'} \geq 0$, $r'_{\theta} = -\Upsilon\frac{\phi}{\theta} < 0$, where $\Upsilon = \frac{\frac{1}{\sigma}\phi(\kappa')(1+r')B'}{G_{r'}} > 0$.

Proof of Proposition 1 *Suppose that* $y_D = 0$ *and* $y_{B'} = 0$. *Plugging these conditions in* $Z_{B'}$ *one obtains*

$$B' = -\frac{\left(1+r'\right)\widetilde{E}y'_D}{r'_B\left[1-\Phi(\kappa')+\widetilde{E}y'_D\right]} < 0,$$

that is, debt would be negative which violates the non-negativity constraint on debt.■

A2. Numerical Solution

Discretization.- The following table provides the relevant information about the discretization of the variables.

Original variable	Discretized variable	Grid of points	Number of gridpoints	Lower Bound	Upper Bound
		Discretization of variables			
x	$x\,(m)$	$m = 1, ..., N_x$	$N_x = 151$	-6000	6000
θ	$\theta\,(s)$	$s = 1, ..., N_\theta$	$N_\theta = 11$	$\mu_\theta - 3\sigma_\theta$	$\mu_\theta + 3\sigma_\theta$
K	$K\,(k)$	$k = 0, ..., N_K$	$N_K = 31$	0	3000
B	$B\,(j)$	$j = 0, ..., N_B$	$N_B = 51$	0	1000
$B\,(1+r)$	$\widetilde{B}\,(i)$	$i = 0, ..., N_{\widetilde{B}}$	$N_{\widetilde{B}} = 51$	0	2000
H	$H\,(h)$	$h = 0, ..., N_H$	$N_H = 31$	0	1000
L	$L\,(l)$	$l = 0, ..., N_L$	$N_L = 1352$	0	1350

The gridsize of each variable is the segment between the variable's upper and lower bound divided the number of gridpoints.[6]

The mean and the variance of productivity θ, which follows an AR(1) process, are $\mu_\theta = \frac{\mu}{1-\rho}$ and $\sigma_\theta = \frac{\sigma}{\sqrt{1-\rho^2}}$; its probability distribution function is also discretized:

$$g\left(s'|s\right) = \Pr(s'|s) = \Phi\left(\frac{\theta(s') - \gamma\theta(s) + \Delta/2 - \mu}{\sigma}\right) - \Phi\left(\frac{\theta(s') - \gamma\theta(s) - \Delta/2 - \mu}{\sigma}\right)$$

where the gridsize is $\Delta = \frac{6\sigma}{N_\theta}$.

Solving the DP-problem

1. Compute the static rules for L, B', and x.

   Flexible labor: For each combination $K\,(k)$, $H\,(h)$, $\theta\,(s)$ find the root of Eq. (**??**) and assign it to its discrete counterpart, that is, $l = l\,(k, h, s)$. Negative values of L imply that $l = 0$.

   Debt: For each combination $x\,(m), K'\,(k')$ find B' from Eq. (**??**) and assign it to the ordinal $j' = j\,(m, k')$

   Internal resources: For each combination $K\,(k)$, $\widetilde{B}\,(i)$, $H\,(h)$, $H\,(h_{-1})$, $L\,(l)$, $\theta\,(s)$ find x from Eq. (6) and assign it to the ordinal $m = m\,(k, i, h, h_{-1}, l, s)$.

2. For each combination k', i', h, s' create the array $V_n(k', i', h, s') = 0$, $n = 0$.

3. Find $\underline{s}'\,(k', i', h) = \arg\min_s V_n(k', i', h, s')$ s. t. $V_n(k', i', h, s') \geq V_n(0, 0, 0, s')$.

4. For each combination k', i', h, s integrate over all admissible values of s:

$$EV(k', i', h, s) = \sum_{s'=1}^{\underline{s}'-1} V_n(0, 0, 0, s')g(s'|s) + \sum_{s'=\underline{s}'}^{N_\theta} V_n(k', i', h, s')g(s'|s).$$

[6] For K, B, $\widetilde{B}$, H, and L the gridsize is the segment between the upper and lower bound divided by the number of gridpoints minus one. Ordinals from one to N are assigned to the gridpoints, while the ordinal zero is reserved to express $K\,(0) = B\,(0) = \widetilde{B}\,(0) = H\,(0) = L(0) = 0$.

5. **Equilibrium interest rate.** For each combination k', j', h, s $(j' \neq 0)$

   (a) Compute $\widetilde{B} = B(j')(1+\rho)$, assign it to the ordinal i' and determine $\underline{s}'_0 = \underline{s}'(k', i', h)$.

   (b) Compute $r' = \frac{(1+\rho)}{g(\underline{s}'_0|s)} - 1$, which comes from Eq. (3).

   (c) Compute $\widetilde{B} = B(j')(1+r')$, assign it to the ordinal i' and determine $\underline{s}'_1(k', i', h)$.

   (d) If $\underline{s}'_1 = \underline{s}'_0$, keep $i' = i'(k', j', h, s)$; otherwise set $\underline{s}'_0 = \underline{s}'_0 + 1$ and go back to b.

   For each combination k', h, s, set $i'(k', 0, h, s) = 0$.

6. For each combination m, s, h construct

$$W(m,k,s;h) = \max_{k'}\left\{x(m) - c^k(k,k') - K'(k') + B'(j') + \frac{1}{1+\rho}EV(k',i',h,s)\right\},$$

   where $j' = j'(m,k,k')$ and $i = i(k', j', h, s)$.

7. For each combination k, i, h_{-1}, s update V_n:

$$V_n(k,i,h_{-1},s) = \max_h W(m,k,s;h),$$

   where $m = m(k,i,h,h_{-1},l,s)$ and $l = l(k,h,s)$.

8. Go to 2, if the tolerance criterion ω is not met, that is, if

$$\max|V_n(k,i,h_{-1},s) - V_{n-1}(k,i,h_{-1},s)| > \omega.$$

9. **Policy rules**:

   (a) Repeat 6 and compute the solution $k = k(m,k,s;h)$ for each combination $m, k, s; h$.

   (b) Repeat 7 and compute the solution $h^*(k,i,h_{-1},s) = \arg\max_h W(m,k,s;h)$, which determines the other policy rules:

$$\begin{aligned} l^*(k,i,h_{-1},s) &= l(k,h^*,s), \\ k^*(k,i,h_{-1},s) &= k(m^*,k,s;h^*), \text{ and} \\ j^*(k,i,h_{-1},s) &= j(m^*,k^*), \end{aligned}$$

   where $m^* = m(k,i,h^*,h_{-1},l^*,s)$.

A3. Sample selection

The original information for 94192 observations of 19473 firms. The first section excludes firms that change activity, merge or split, have less than five observations available or that are public or non-manufacturing. These filters leave 27704 observations of 3005 firms in the sample, being the most important selection to exclude non-manufacturing firms, which alone leaves 40738 observations of 7587 firms in the sample. The next most important selection results from leaving out of the sample firms that have at least one observation with a non-positive value of the following variables: value of production, value of net purchases, net fixed assets, gross capital formation, total outside resources-debt with providers, gross value added, net worth, cumulative downpayment, or whose net fixed assets grow more than three times. This selection leaves 10787 observations of 1217 firms in the sample.

The definitions of the variables correspond to the following definitions of the database:

Capital =Net fixed assets;
Debt =Short term debt with cost;
Rigid labor=Number of workers with permanent contracts;
Flexible labor=Number of workers with temporary contracts.

Table A1 shows the structure of the panel by year. There is a relatively fair representation of all periods of interest in the sample. For 568 of the 1217 firms, that is for 48%, there is information before and after the 1984 labor market reform. Table A2 gives an idea of the longitudinal dimension of the panel. There is a relatively large proportion of firms that stay in the sample for a long time: 43% of the firms have 10 or more observations.

[Insert Table A1 and Table A2 here]

A4. Likelihood function

The construction of the likelihood function also exploits the discretization of the continuous variables done to solve the DP problem. The discretized densities used to define ψ are

$$\begin{aligned} \varphi_Y(\iota^{obs},\iota) &= \Phi\left(\frac{Y^{obs}\left(\iota^{obs}\right)-Y\left(\iota\right)+\Delta_Y/2}{\sigma_Y}\right)-\Phi\left(\frac{Y^{obs}\left(\iota^{obs}\right)-Y\left(\iota\right)-\Delta_Y/2}{\sigma_Y}\right), \\ Y &= K,B,H,L;\ \iota=k,j,h,l. \end{aligned}$$

Then, the computation of the likelihood contribution proceeds as follows.

Initial period, $t=1$**:** Assuming that the observations of capital and debt, characterized by the ordinals k_1^{obs} and j_1^{obs}, are the 'true' ones, find out 'true' rigid labor h_0 and productivities s_0 and s_1. Let

$$\begin{aligned} \psi_1 &= \varphi_K\left(k_2^{obs},k_2\right)\varphi_B\left(j_2^{obs},j_2\right)\varphi_H\left(h_1^{obs},h_1\right)\varphi_L\left(l_1^{obs},l_1\right), \\ \text{then } \widehat{\psi}_1 &= \max_{h_0,s_0,s_1}\psi_1 \text{ and } (h_0,s_0,s_1)=\arg\max\psi_1, \end{aligned}$$

where $(k_2,j_2,h_1,l_1)=(k',j',h,l)\left(k_1^{obs},i_1,h_0,s_1\right)$, and $i_1=i'\left(k_1^{obs},j_1^{obs},h_0,s_0\right)$. The likelihood contribution is $\mathcal{L}_1=\widehat{\psi}_1\times g\left(s_1,s_0\right)$ and store the 'true' values k_2, i_2, h_1, and s_1.

Intermediate periods, $t=2,...,T-1$**:** Using the 'true' values of k_t, i_t, and h_{t-1}, determine the current likelihood contribution.

$$\begin{aligned} \text{Let } \psi_t &= \varphi_K\left(k_{t+1}^{obs},k_{t+1}\right)\varphi_B\left(j_{t+1}^{obs},j_{t+1}\right)\varphi_H\left(h_t^{obs},h_t\right)\varphi_L\left(l_t^{obs},l_t\right), \\ \text{then } \widehat{\psi}_t &= \max_{s_t}\psi_t, \text{ and } s_t=\arg\max\psi_t, \end{aligned}$$

where $(k_{t+1}, j_{t+1}, h_t, l_t) = (k', j', h, l)(k_t, i_t, h_{t-1}, s_t)$, and $i_{t+1} = i'(k_{t+1}, j_{t+1}, h_t, s_t)$. Using s_{t-1}, compute the likelihood contribution: $\mathcal{L}_t = \widehat{\psi}_t \times g(s_t, s_{t-1})$ and store the 'true' values k_{t+1}, i_{t+1}, h_t, and s_t.

Last Period, $t = T$ **:** There are no more observations for capital and debt next period; the likelihood contribution only accounts for the two types of labor. Using the 'true' values of k_T, i_T, and h_{T-1}, determine the current likelihood contribution. Let

$$\begin{aligned} \psi_T &= \varphi_H\left(h_T^{obs}, h_T\right)\varphi_L\left(l_T^{obs}, l_T\right), \\ \text{then } \widehat{\psi}_T &= \max_{s_T} \psi_T \text{ and } s_T = \arg\max \psi_T, \end{aligned}$$

where $(h_T, l_T) = (h, l)(k_T, i_T, h_{T-1}, s_T)$. Using s_{T-1}, compute the likelihood contribution $\mathcal{L}_T = \widehat{\psi}_T \times g(s_T, s_{T-1})$.

Once the likelihood contributions are computed, take logs and add them up, that is, compute the likelihood function from Eq. (7).

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Table 1: Descriptive Statistics by period and firm size

Variable	All	1983-1984 Small	1983-1984 Med.	1983-1984 Large	1985-1989 Small	1985-1989 Med.	1985-1989 Large	1990-1996 Small	1990-1996 Med.	1990-1996 Large
Obs.	10787	250	346	411	1910	1778	1654	1437	1471	1530
Capital K										
Average	455	36	171	1179	32	164	1127	33	160	1211
St. Dev.	(741)	(21)	(65)	(918)	(20)	(64)	(902)	(21)	(65)	(969)
K/N	3.18	0.68	1.67	3.37	0.80	1.86	3.47	1.07	2.44	4.02
$\Delta K/K$ %	3.3	-5.6	-9.2	-4.9	3.4	5.5	4.7	-1.4	2.3	3.3
Debt B										
Average	207	53	145	459	47	146	427	43	127	443
St. Dev.	(282)	(71)	(176)	(374)	(70)	(176)	(364)	(88)	(162)	(375)
B/N	1.44	1.11	1.68	1.40	1.20	1.67	1.31	1.40	1.92	1.47
B/K	0.45	1.64	1.01	0.42	1.50	0.90	0.38	1.31	0.79	0.37
$\Delta B/B$ %	0.5	15.1	22.5	5.9	-2.2	1.7	0.7	-1.9	0.7	-1.1
Rigid Labor H										
Average	123	51	92	319	34	75	281	24	51	247
St. Dev.	(189)	(42)	(67)	(282)	(29)	(63)	(259)	(24)	(51)	(247)
$\Delta H/H$ %	0.1	-1.8	0.2	-1.2	0.5	0.6	0.7	-2.5	-0.4	-0.3
Flexible Labor L										
Average	21	4	7	18	5	12	42	6	14	54
St. Dev.	(60)	(17)	(23)	(66)	(9)	(25)	(95)	(9)	(22)	(101)
L/N %	15.8	9.2	7.5	5.9	11.2	13.3	12.9	20.1	21.6	17.8
$\%(L=0)$	32.5	61.6	54.3	45.7	47.9	36.5	28.5	28.0	19.8	16.3
$\Delta L/L$ %	6.8	31.4	3.1	21.8	10.0	14.6	18.5	1.9	-0.1	-1.5
Total Labor N										
Average	144	55	99	337	39	87	323	31	65	301
St. Dev.	(220)	(46)	(68)	(297)	(31)	(68)	(300)	(22)	(51)	(319)
$\Delta N/N$ %	1.1	0.5	0.4	-0.1	1.7	2.3	2.7	-1.7	-0.3	-0.5

Note 1. Data on capital and debt are given in million pesetas of 1987.
Note 2. A firm's size is determined by its position in the distribution of capital. Large firms are in the upper third; medium sized firms are in the middle third; and small firms are in the lower third of the distribution of capital.

Table 2: Parameter Estimates

Parameters	Estimates
Production function	
α	0.2625
β	0.6732
γ	0.8893
λ	0.2549
Depreciation	
δ_k	0.1565
δ_h	0.0100
Wages	
w_h	2.0581
w_l	0.6589
Risk-free interest rate	
ρ	0.0519
Labor Adjustment Costs	
F	2.4116
Stochastic Process	
ϕ	0.8925
μ	0.2103
σ	0.2058
Capital Adjustment Costs	
a	1.8420
Borrowing Constraint	
$-\overline{D}$	143.0657
Prediction Errors	
σ_K	249.5085
σ_B	205.2214
σ_H	30.1482
σ_L	75.2699
Log-Likelihood	
$-\ln \mathcal{L}$	146383.81

Table 3a: Actual and Predicted Variables

Year	Capital				Debt			
	Act.	Pred.	χ^2	R^2	Act.	Pred.	χ^2	R^2
1983	595	595	0.00	1.00	240	240	0.02	1.00
1984	509	548	2.69	0.99	257	261	1.86	0.97
1985	448	513	6.07	0.97	243	273	9.73	0.91
1986	400	454	6.31	0.96	200	243	20.15	0.85
1987	394	430	8.33	0.95	186	227	23.69	0.81
1988	401	421	4.68	0.93	183	219	21.83	0.81
1989	422	429	6.10	0.92	186	216	20.08	0.80
1990	450	437	7.70	0.91	203	212	2.91	0.76
1991	476	451	11.33	0.90	221	217	1.83	0.79
1992	474	446	9.00	0.90	222	210	1.48	0.78
1993	471	455	8.40	0.91	210	202	5.52	0.75
1994	466	461	6.73	0.91	199	204	3.94	0.73
1995	485	474	12.40	0.89	197	203	3.79	0.73
1996	531	492	17.86	0.88	198	203	2.55	0.73
$\sqrt{n^{-1}\Sigma e^2}$	270.83				217.00			

Note. The χ^2-statistic is computed using 5 bins. Critical values are: $\chi^2_{(4)} = 9.49$, at 5% significance level, and $\chi^2_{(4)} = 14.86$, at 0.5% significance level.

Table 3b: Actual and Predicted Variables

Year	Rigid Labor				Flexible Labor			
	Act.	Pred.	χ^2	R^2	Act.	Pred.	χ^2	R^2
1983	185	187	0.09	1.00	8	0	0.00	0.00
1984	163	163	0.46	0.99	9	0	0.00	0.00
1985	148	147	0.19	0.99	10	9	0.00	0.49
1986	130	130	0.37	0.99	11	9	0.33	0.61
1987	122	120	1.47	0.99	14	10	0.25	0.58
1988	117	116	0.01	0.98	18	11	0.20	0.47
1989	116	115	1.11	0.98	24	16	0.50	0.67
1990	115	115	3.32	0.98	23	13	0.67	0.40
1991	115	116	0.18	0.98	24	13	0.80	0.48
1992	110	111	0.50	0.98	26	14	1.34	0.62
1993	107	110	0.95	0.98	23	14	2.33	0.76
1994	105	109	0.96	0.98	24	13	0.51	0.63
1995	107	110	0.49	0.98	26	14	1.00	0.61
1996	111	113	0.60	0.98	26	16	0.20	0.46
$\sqrt{n^{-1}\Sigma e^2}$	49.33				94.51			

Note. The χ^2-statistic is computed using 5 bins. Critical values are: $\chi^2_{(4)} = 9.49$, at 5% significance level, and $\chi^2_{(4)} = 14.86$, at 0.5% significance level.

Table 4a: Regime Changes

Year	Capital						Debt					
$-\overline{D}$	$<\infty$				∞		$<\infty$				$=\infty$	
C,F	>0		$=0$		≥ 0		>0		$=0$		≥ 0	
L	≥ 0	$=0$	≥ 0	$=0$	≥ 0	$=0$	≥ 0	$=0$	≥ 0	$=0$	≥ 0	$=0$
1983	595	595	595	595	595	595	240	240	240	240	240	240
1984	548	548	548	548	548	548	261	261	261	261	261	261
1985	513	513	513	513	513	513	273	273	273	273	273	273
1986	454	457	457	456	506	507	243	272	252	251	22	22
1987	430	439	437	436	531	536	227	289	253	253	21	21
1988	421	436	433	433	570	581	219	290	253	252	14	14
1989	429	447	444	443	619	637	216	292	249	247	20	20
1990	437	458	453	453	652	689	212	294	245	244	12	12
1991	451	473	469	469	674	730	217	306	251	251	15	15
1992	446	469	465	466	664	732	210	306	252	252	23	23
1993	455	481	476	477	688	767	202	315	258	258	10	10
1994	461	490	486	485	708	795	204	327	272	271	10	10
1995	474	508	501	501	731	824	203	347	284	285	10	10
1996	492	534	524	525	752	847	203	368	303	305	10	10

Table 4b: Regime Changes

Year	Rigid Labor						Flexible Labor					
$-\overline{D}$	$<\infty$				∞		$<\infty$				$=\infty$	
C,F	>0		$=0$		≥ 0		>0		$=0$		≥ 0	
L	≥ 0	$=0$	≥ 0	$=0$	≥ 0	$=0$	≥ 0	$=0$	≥ 0	$=0$	≥ 0	$=0$
1983	187	187	187	187	187	187	0	0	0	0	0	0
1984	163	163	163	163	163	163	0	0	0	0	0	0
1985	147	145	34	39	142	142	9	0	43	0	9	0
1986	130	125	34	40	123	123	9	0	37	0	11	0
1987	120	115	34	38	111	113	10	0	36	0	13	0
1988	116	110	34	39	107	108	11	0	38	0	16	0
1989	115	110	39	44	109	112	16	0	42	0	24	0
1990	115	111	34	40	111	115	13	0	41	0	23	0
1991	116	113	37	43	111	118	13	0	40	0	24	0
1992	111	109	36	42	108	113	14	0	41	0	21	0
1993	110	109	34	39	108	114	14	0	43	0	21	0
1994	109	108	34	39	108	115	13	0	41	0	20	0
1995	110	110	37	42	111	120	14	0	43	0	25	0
1996	113	118	48	56	129	158	16	0	52	0	65	0

Table A1: Structure of the Panel

Year	Obs.	Freq.
1983	439	4.07
1984	568	5.27
1985	688	6.38
1986	849	7.87
1987	964	8.94
1988	972	9.01
1989	959	8.89
1990	910	8.44
1991	841	7.80
1992	830	7.69
1993	767	7.11
1994	713	6.61
1995	678	6.29
1996	609	5.65
Total	10787	100.00

Table A2: Balance of the Panel

Obs. by firm	Obs.	%	Firms	%
5	1115	10.34	223	18.32
6	1116	10.35	186	15.28
7	721	6.68	103	8.46
8	864	8.01	108	8.87
9	846	7.84	94	7.72
10	1000	9.27	100	8.22
11	1166	10.81	106	8.71
12	852	7.90	71	5.83
13	741	6.87	57	4.68
14	2366	21.93	169	13.89
Total	10787	100.00	1217	100.00

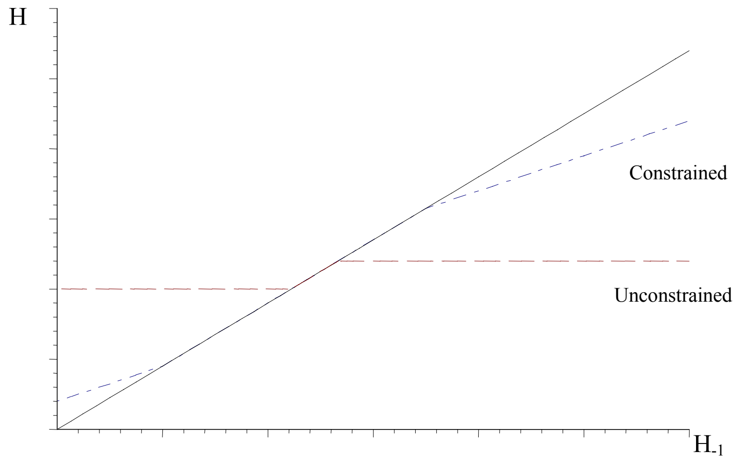

Figure 1: Rigid Labor H as a function H_{-1}

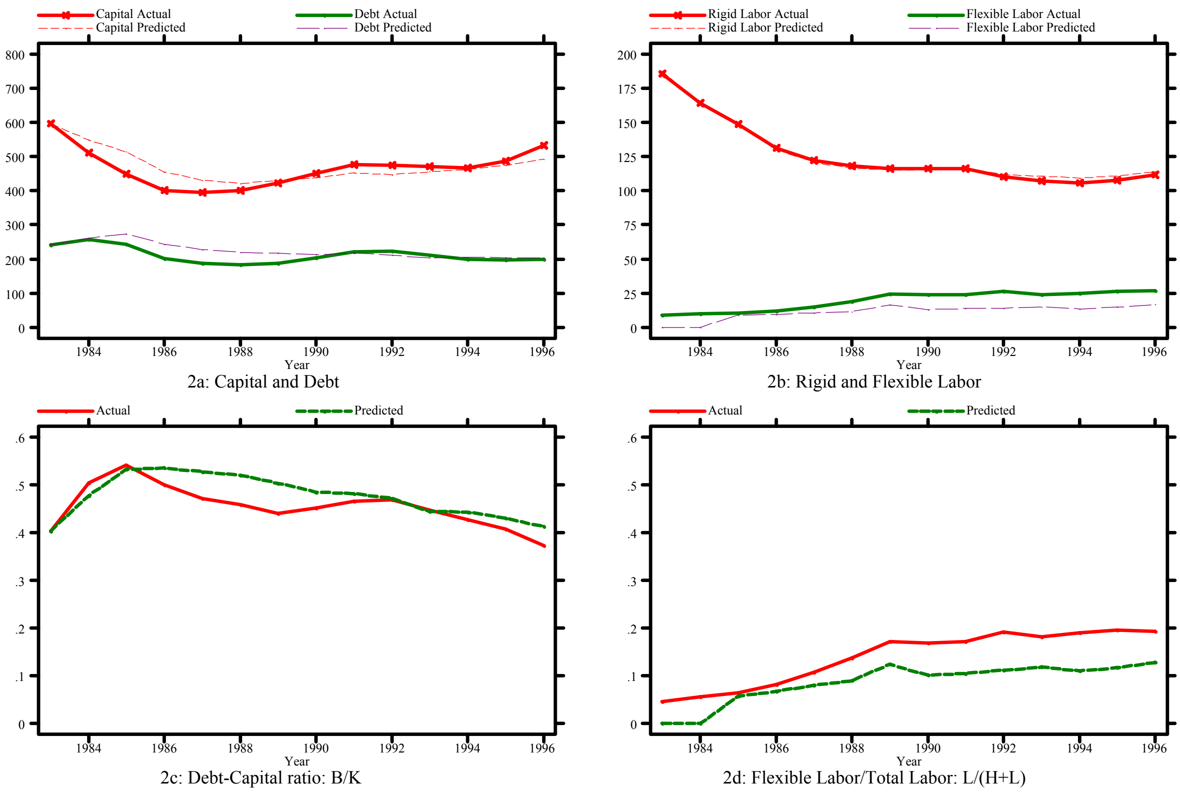

Figure 2: Actual and Predicted Variables

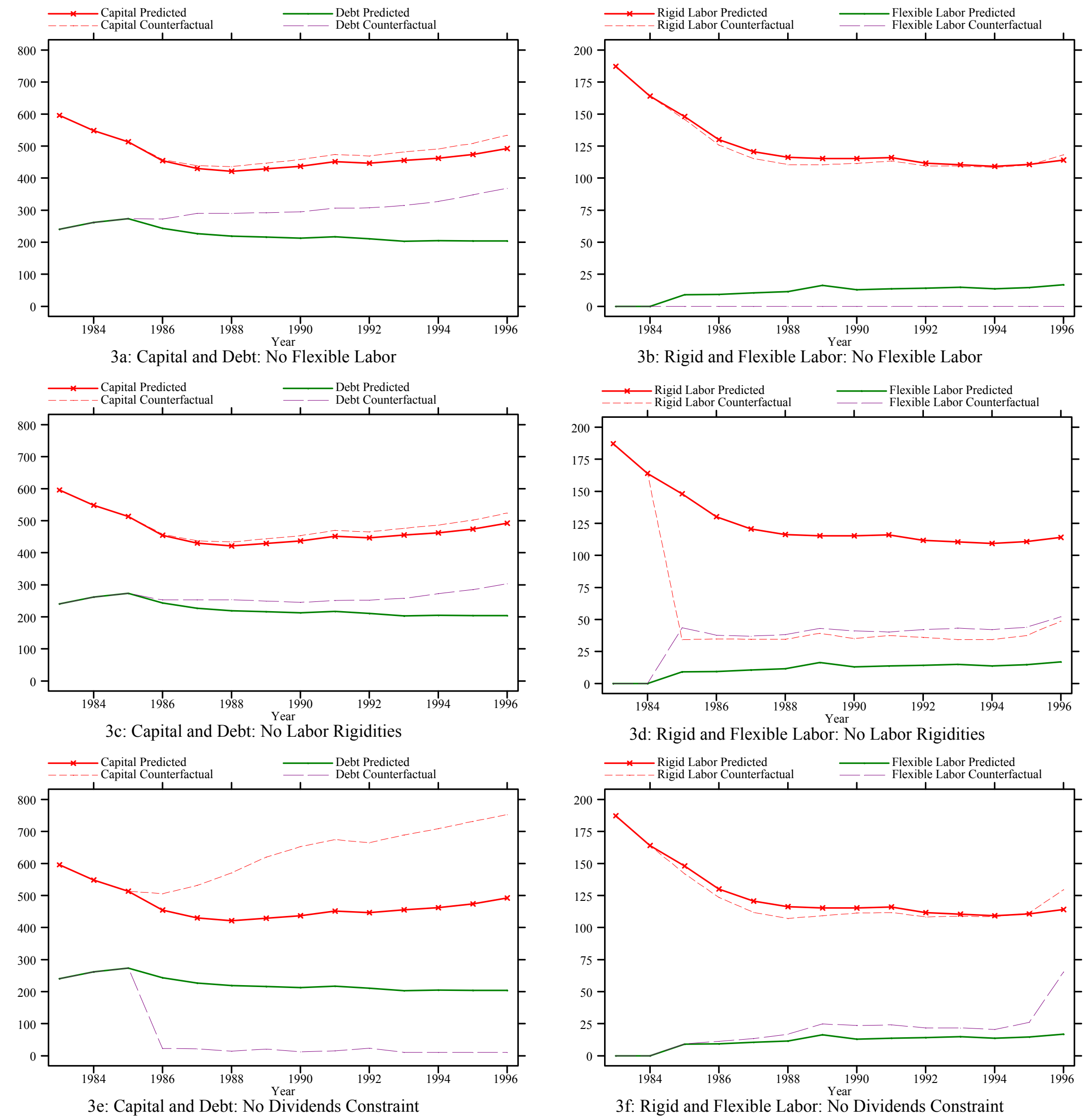

Figure 3: Capital, Debt, and Labor after Regime Changes: (i) No Flexible Labor, (ii) No Labor Rigidities, (iii) No Dividends Constraint