Job Creation and Investment in Imperfect Capital and Labor Markets*

PRELIMINARY - COMMENTS WELCOME - PLEASE DO NOT QUOTE

Sílvio Rendon†

University of Western Ontario

October 2003

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 in dividends, and imperfect labor markets, contained in legal firing and hiring costs applicable to some workers, firms use flexible labor contracts to alleviate financial constraints. The optimal policy rules of theoretical the 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 labor market rigidities are removed.

JEL Classification: J23, J32, E22, G31.
Keywords: Job Creation, Employment, Investment, Adjustment Costs, Liquidity Constraints.

*Updates of this paper can be downloaded at `http://publish.uwo.ca/~srendon`.

†E-mail address: srendon@uwo.ca. I started this project when I was a Research Fellow at the Bank of Spain. I am thankful to the bank's research team for several fruitful discussions and for providing the dataset. I also thank participants of seminars at LACEA, University of Tartu, IZA, Universitat Pompeu Fabra, FEDEA for their comments and valuable suggestions. Financial support of the Spanish Ministry of Science and Technology (Grant SEC 2001-0674) is gratefully acknowledged. Valeria Arza provided excellent research assistance at an early stage of this project. The usual disclaimer applies.

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 were not directed to reduce the costs of firing the already employed, protected by strong unions, but to create a new type of contract that, once expired, would allow firms to costlessly lay off newly hired workers. Thus, these reforms created 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 labor market reforms, (ii) elimination of labor market rigidities, and (iii) relaxation 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 did substitute capital. The second experiment shows that removing labor market rigidities would imply an initial substantial reduction in permanent labor and an increase in subsequent periods, but it would produce a modest increase in capital and a slow decrease in debt. On the contrary, relaxing financial constraints would generate an important increase in capital accumulation, a sharp decrease in firms' debt and also an initial reduction followed by an increase 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 and hiring 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 and hiring 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 real economic theory (see Bernanke, Gertler & Gilchrist (1999) for a survey). Under liquidity constraints the Modigliani & 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 explicitly. 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 and hiring 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 first labor reform was done to counteract the sharp increase in unemployment suffered during the 'transition phase' to a free economy. This reform basically created temporay labor in Spain, so that after 1984 there is an important expansion of this type of contract. At the same time, there is evidence that Spanish firms face significant financial constraints, so that financial variables have an important on firms' investment.(Alonso-Borrego & Bentolila 1994, Estrada & Vallés 1995) Therefore, the Spanish economy illustrates

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

well the kind of the imperfections faced by several European economies.

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

2 Model

I use a dynamic model where firms choose investment, two types of labor and debt to maximize the discounted sum of the expected value of their future stream of dividends. It is a neo-classical model of investment on the lines of Jorgenson (1963), extended to include hiring and firing decisions as well as liquidity constraints and bankruptcy.[2]

2.1 The Firm's Problem

The firm resides 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 or 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

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

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, both labor costs, adjustment costs of rigid labor and net debt variation. The firm operates in a risky environment, captured by a total factor productivity θ that follows a Markov process $P(\theta'|\theta)$ parameterized as an AR(1) process: $\theta' \sim N\left(\mu + \phi\theta, \sigma^2\right)$. Productivity is

[2] This model is basically Pratap & Rendon (2003), extended to allow for imperfect labor markets.

[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.

observed by the firm and the lenders before investment, employment and borrowing decisions are made. Technology is contained in a Cobb-Douglas production function in capital and efficiency units of labor, with parameters α and β, respectively. Efficiency units of labor on its turn are determined with a CES technology with parameters γ and λ.

Capital is accumulated following the law of motion:

$$K' = (1 - \delta_k)K + I,$$

where δ_k is the depreciation rate of capital. The wage rate of rigid labor is w_H, and the wage rate of flexible labor is w_L. The firm operates in an environment of rigid labor markets: while flexible labor can be adjusted at no cost, adjusting rigid labor implies incurring in hiring and firing costs. In this context, it is sensible to assume a linear adjustment cost function for labor:

$$c(H_{-1}, H) = C \max\left[(H - (1 - \delta_h)\, H_{-1}), 0\right] - F \min\left[(H - (1 - \delta_h)\, H_{-1}), 0\right]$$

where C is the hiring cost and F is the firing cost, both in terms of unit variation in rigid labor. Workers quit their jobs at an exogenous rate δ_h without producing any cost for firms. The labor adjustment cost function captures the labor market imperfection; the capital market imperfection is that the firm is not allowed to issue fresh equity, that is, dividends are constrained to be nonnegative:

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

In the current period the firm pays debt B at the interest rate r, determined in the past period, and contracts debt B', which is paid in the next period. 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 firm exits the market or goes bankrupt, if its value falls below zero. In that case, the firm cannot meet its current obligations out of their current assets and shuts down forever. Competitive lenders, who are aware of that possibility, establish a debt contract so that they earn zero expected profits. Assuming that 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 zero profit condition:

$$G(r') = \pi(1+r')B' - (1+\rho)B' = 0,$$

where π is the probability of survival. The first term is the expected return of the lender while the second term is the opportunity cost of the funds. This equation pins down the interest rate and is explained below in greater detail.

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 in its value is nonnegative 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:

$$\begin{aligned} V(K, H_{-1}, (1+r)B, \theta) \quad = \quad & \max_{K', H, L, B'} \Big\{ \theta K^{\alpha} (H^{\gamma} + \lambda L^{\gamma})^{\frac{\beta}{\gamma}} + (1-\delta_k)K - K' \\ & -w_H H - c(H_{-1}, H) - w_L L - (1+r)B + B' \\ & \quad + \frac{1}{1+\rho} E \max\left[V(K', H, (1+r')B', \theta'), 0\right] \Big\} \\ & \text{subject to (1), and (2).} \end{aligned}$$

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., $V_K > 0, V_{H_{-1}} \lesseqqgtr 0, V_{(1+r)B} < 0, V_{\theta} > 0$. Before deciding on the choice variables, the firm determines an exit rule. Let the lowest productivity that leaves the firm in business be

$$\underline{\theta} = \{\theta \,|V(K, H_{-1}, (1+r)B, \theta) = 0\};$$

then, the exit rule implies that

$$\begin{aligned} \text{if } \theta \ &\geq \ \underline{\theta}, \qquad \text{the firm stays;} \\ \text{if } \theta \ &< \ \underline{\theta} \qquad \text{the firm exits.} \end{aligned}$$

Hence, the probability of survival next period is $\pi = \Pr(\theta' > \underline{\theta}'|\theta) = 1 - \Phi(\kappa')$, where $\kappa' = \frac{\underline{\theta}' - \gamma\theta - \mu}{\sigma}$ 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:

$$\begin{aligned} \underline{\theta}_{K'} &= -\frac{V_{K'}}{V'_{\theta}} < 0; \qquad & \underline{\theta}'_{B'} = -\frac{V_{(1+r')B'}}{V'_{\theta}}\left(1+r'\right) > 0; \\ \underline{\theta}_{r'} &= -\frac{V_{(1+r')B'}}{V'_{\theta}}B' > 0; \qquad & \underline{\theta}'_{H} = -\frac{V_H}{V'_{\theta}} \lesseqgtr 0; \end{aligned}$$

which imply that the survival probability increases in capital, decreases in debt and in the interest rate, and has an ambiguous sign for lagged in rigid labor. Having determined the effect of the state variables on the firm's survival probability, I define the firm-specific interest rate from the zero-profit condition:

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

This equation gives us the supply for debt faced by the firm. 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, $r'_{K'} = \underline{\theta}'_{K'}\Upsilon < 0$, $r'_{H} = \underline{\theta}'_{H}\Upsilon \lesseqgtr 0$, and $r'_{B'} = \underline{\theta}'_{B'}\Upsilon > 0$, where $\Upsilon = \frac{\lambda(\kappa')(1+r')}{1-\lambda(\kappa')(1+r')\underline{\theta}'_{r'}} > 0$, and $\lambda\left(\kappa'\right) = \frac{\frac{1}{\sigma}\phi(\kappa')}{1-\Phi(\kappa')} > 0$ is the inverse Mills's ratio, which is positive as truncation occurs from below. The interest rate ranges between ρ, if its survival were guaranteed, and infinity, if it goes bankrupt next period with centainty. More details can be found in Appendix A1.

2.2 Optimal Policy

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

$$\begin{aligned} Z\left(K',H,L,B'\right) &= \left(1+y_D\right)\Big[\theta K^{\alpha}\left(H^{\gamma}+\lambda L^{\gamma}\right)^{\frac{\beta}{\gamma}} + (1-\delta)K - K' \\ &\quad -w_H H - c(H_{-1},H) - w_L L - (1+r)B + B'\Big] - y_D\overline{D} \\ &\quad + \frac{1}{1+\rho}\int \max\left[V(K',H,\left(1+r'\right)B',\theta'),0\right]dP\left(\theta'|\theta\right) + y_B B' \end{aligned}$$

The first order conditions for this problem are then

$$\begin{aligned}
Z_{K'} &= -(1+y_D)+\frac{1}{1+\rho}\widetilde{E}V_{K'}=0\\
Z_H &= D_H(1+y_D)+\frac{1}{1+\rho}\widetilde{E}V_H=0\\
Z_{B'} &= 1+y_D+\frac{1}{1+\rho}\widetilde{E}V_{B'}+y_B=0\\
Z_L &= (1+y_D)\left[\beta\lambda\theta K^{\alpha}(H^{\gamma}+\lambda L^{\gamma})^{\frac{\beta}{\gamma}-1}L^{\gamma-1}-w_L\right]=0\\
Z_{y_D} &= x-K'+B'-\overline{D}=0,\\
Z_{y_B} &= B'=0,
\end{aligned}$$

$$\begin{aligned}
\text{where } \widetilde{E}V_i &= \int_{\theta'\geq\underline{\theta}}(1+y_D')\,D_i'dP(\theta'|\theta)\,,\ i=\{K',H,B'\}\,,\\
D_{K'}' &= \alpha\theta'K'^{\alpha-1}(H'^{\gamma}+\lambda L'^{\gamma})^{\frac{\beta}{\gamma}}+(1-\delta)-r_{K'}'B',\\
D_H &= \beta\theta K^{\alpha}(H^{\gamma}+\lambda L^{\gamma})^{\frac{\beta}{\gamma}-1}H^{\gamma-1}-w_H-c_2,\\
D_H^{'} &= -r_HB'-c_1',\\
D_{B'}^{'} &= -(1+r')-r_{B'}'B',
\end{aligned}$$

and x are the firm's internal resources determined by the state variables and the choice of rigid and flexible labor:

$$x=\theta K^{\alpha}(H^{\gamma}+\lambda L^{\gamma})^{\frac{\beta}{\gamma}}+(1-\delta)K-w_HH-c(H_{-1},H)-w_LL-(1+r)B \qquad (4)$$

We have six equations to determine six variables, four choice variables and two Lagrange multipliers; we can reduce them to three. Notice that he first order condition for flexible labor Z_L is static, that is, it depends on current capital and productivity, both state variables, and on the choice of current rigid labor. Hence, the interior solution for flexible labor is defined by:

$$L^i(K,H,\theta)=\left\{L\,\middle|\,\beta\lambda\theta K^{\alpha}(H^{\gamma}+\lambda L^{\gamma})^{\frac{\beta}{\gamma}-1}L^{\gamma-1}-w_L=0\right\}. \qquad (5)$$

For $H=0$ there is an explicit solution: $L^i(K,0,\theta)=\left(\frac{\beta\theta\lambda^{\frac{\beta}{\gamma}}K^{\alpha}}{w_L}\right)^{\frac{1}{1-\beta}}\equiv L_0$. Notice that $L^i_\theta > 0$ and $L^i_K > 0$ always;

$$\begin{aligned} \text{if } \gamma &< \beta \text{, then } L^i_H > 0 \text{ and } L^i > L_0, \\ \text{if } \gamma &> \beta \text{, then } L^i_H < 0 \text{ and } L^i < L_0, \\ \text{if } \gamma &= \beta \text{, then } L^i_H = 0 \text{ and } L^i = L_0. \end{aligned}$$

Obviously, if $\gamma = \beta$, there is an explicit solution: $L^i(K, H, \theta) = L_0$. Also if $\gamma = 1$, there is an explicit solution: $L^i(K, H, \theta) = L_0 - \frac{H}{\lambda}$. A negative interior solution, is rule out:

$$L(K, H, \theta) = \max\left(L^i(K, H, \theta), 0\right) \tag{6}$$

Notice also that the first order condition $Z_H = 0$ holds only if the firm adjusts H. Because the adjustment cost function of rigid labor has a discontinuous derivative:

$$c_2 = \begin{cases} C, \text{ if } H > (1 - \delta_h) H_{-1}, \\ -F, \text{ if } H < (1 - \delta_h) H_{-1}, \\ 0, \text{ if } H = (1 - \delta_h) H_{-1}, \end{cases}$$

adjustments in rigid labor yield two possible solutions:

$$\begin{aligned} H_C &= \left\{ H \left| \widetilde{E}V_H = -\widetilde{E}V_{K'} \left. D_H \right|_{c_2 = C} \right. \right\}, \text{ if } H > (1 - \delta_h) H_{-1}, \\ H_F &= \left\{ H \left| \widetilde{E}V_H = -\widetilde{E}V_{K'} \left. D_H \right|_{c_2 = -F} \right. \right\}, \text{ if } H < (1 - \delta_h) H_{-1}. \end{aligned}$$

And given that $\left. Z_H \right|_{c_2=-F} > \left. Z_H \right|_{c_2 = C}$, then $H_F > H_C$, and the solution for rigid labor is selected in the following way:

$$H = \begin{cases} H_C, \text{ if } H_C > (1 - \delta_h) H_{-1}, \\ H_F, \text{ if } H_F < (1 - \delta_h) H_{-1}, \text{ and} \\ (1 - \delta_h) H_{-1}, \text{ if } H_C < (1 - \delta_h) H_{-1} < H_F. \end{cases}$$

Certainly, this solution depends on the state variables and is determined simultaneously with capital and debt. A shorter expression for this solution is

$$H = \min\left(\max\left((1 - \delta_h) H_{-1}, H_C\right), H_F\right). \tag{7}$$

Now, we can combine the first order conditions that apply and write down the three equations that determine capital, debt and rigid labor. Binding dividend and debt constraints give rise to three possible regimes:

Regime I: $y_D > 0$ and $y_{B'} = 0$;

Regime II: $y_D > 0$ and $y_{B'} > 0$;

Regime III: $y_D = 0$ and $y_{B'} > 0$.

There is no Regime IV: at least one constraint must be binding.

Proposition 1 *A firm cannot simultaneously incur 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.*

The three regimes are then summarized by three equations:

Equation	Regime I	Regime II	Regime III
1.	$D = \overline{D}$		$\widetilde{E}V_{K'} = 1 + \rho$
2.	$\widetilde{E}V_{K'} = -\widetilde{E}V_{B'}$	$B' = 0$	
3.	$H = \min\left(\max\left(\left(1-\delta_h\right) H_{-1}, H_C\right), H_F\right)$		

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

Multiplier	Regime I	Regime II	Regime III
$y_D =$	$-1 + \frac{1}{1+\rho}\widetilde{E}V_{K'}$		0
$y_B =$	0	$-\frac{1}{1+\rho}\left(\widetilde{E}V_{K'} + \widetilde{E}V_{B'}\right)$	

This model does not admit an analytical solution; the solution has to be approximated by numerical methods. It will prove useful both for solving the model numerically and for gaining further insights on the optimal solution, to understand the relationship that capital, debt and internal resources maintain at the optimum in each regime. These are

Regime I: $B' = K' - x + \overline{D} > 0$, $K' > x - \overline{D}$;

Regime II: $B' = 0$, $K' = x - \overline{D}$;

Regime III: $B' = 0$, $K' < x - \overline{D}$.

This means that in general the optimal solution for debt is

$$B' = \max\left(K' - x + \overline{D}, 0\right). \tag{8}$$

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:

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

And given that in Regime III the dividend constraint does not bind, only lagged rigid labor through of the adjustment cost and current productivity determine the optimal solution[4]:

$$\begin{aligned} K^{III} &\equiv K^{III}\left(H_{-1}, \theta\right), \\ H^{III} &\equiv H^{III}\left(H_{-1}, \theta\right). \end{aligned}$$

Let $\overline{K}$ be the level of optimal capital in Regime I that sets debt equal to zero:

$$\overline{K} = \left\{ K^I \middle| K^I = x - \overline{D} \right\}, \tag{9}$$

then in Regime II capital and labor are:

$$\begin{aligned} K^{II} &\equiv x|_{H^{II}} - \overline{D}, \\ H^{II} &\equiv H^{II}\left(K, H_{-1}, (1+r)B, \theta\right). \end{aligned}$$

Consequently, in general the optimal solution for capital can be written as

$$K' = \min\left(\max\left(K^I, x - \overline{D}\right), K^{III}\right). \tag{10}$$

The following table summarizes the relationships that capital, debt and internal re-

[4]Rigid labor is determined, simultaneously with capital, from Eq.(7), where H_F and H_C depend on the state variables and capital for each Regime.

sources maintain at the optimum in the three regimes:

Variable	Regime I	Regime II	Regime III
x	$x-\overline{D}<\overline{K}$	$\overline{K}\leq x-\overline{D}\leq K^{III}$	$x-\overline{D}>K^{III}$
K'	K^{I}	$x-\overline{D}$	K^{III}
B'	$K^{I}-x+\overline{D}$	0	0

In this setup current rigid labor is a choice variable which, together with the state variables, determines flexible labor and thus the level of internal resources. Therefore, this table is only informative about the relationship that choice variables maintain at the optimum. In models of investment without labor or with labor in perfect labor markets, internal resources x become a state variable themselves, in which case this table would summarize the optimal solution.

2.3 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. (8) and the interest rate next period r' by Eq. (3). The value function conditional on rigid labor H is then:

$$W\left(x,\theta;H\right)=\max_{K'}\left\{\max\left(x-K',\overline{D}\right)+\frac{1}{1+\rho}E\max\left[V\left(K',H,\left(1+r'\right)B',\theta'\right),0\right]\right\}.$$

In this maximization there is no need for Lagrange multipliers, because Eq. (8), implying that current dividends are $\max\left(x-K',\overline{D}\right)$, takes care of the dividend and the debt constraints. The solution for this problem is contained in the policy rule $K^{w}\left(x,\theta;H\right)$. Optimal debt is obtained from this solution and Eq. (8).

Stage II: Solution for rigid labor

Using Eq. (6) and Eq. (4) 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:

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

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

$L^{*} \equiv L^{*}\left(K, H_{-1}, (1+r)\, B, \theta\right) = L(K, H^{*}, \theta)$, optimal flexible labor, from Eq. (6);

x^{*}, defined as internal resources at the optimum, from Eq. (4);

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

$B^{*} \equiv B^{*}\left(K, H_{-1}, (1+r)\, B, \theta\right) = \max\left(K^{*} - x^{*} + \overline{D}, 0\right)$, optimal debt next period, from Eq. (8).

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 (6) and (8) are used to solve for two instead of four choice variables and that the sequential solution is faster than a simultaneous one.[5]

3 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

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

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 1here]

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, as well as how variables behave according to size, measured as thirds in the distribution of capital, and by time before and after the labor market reform, proxied by the year 1987. Capital grows on average 3.32% by year, being the growth rate higher after 1987. Debt is lower after 1987 for all firm sizes; however, in relative terms debt by worker is higher for the medium sized firms, whereas the debt-capital ratio is monotonically decreasing in firm's size. Firms with a high level of capital, and are therefore more attractive to lenders, rely less on debt for the financial needs than small firms, which are thirsty on financial resources.

In this period, flexible labor experienced a very high expansion, which was responsible for an important part of the expansion of total labor in the eighties and nineties. This growth of flexible labor coincided with a slow growth of rigid labor, suffering from an important reduction in the period before 1987. Noticeably, small and large firms have a lower percentage of flexible labor over the total labor force than medium sized firms. 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, so their labor demand can concentrate in rigid labor. Graphical evidence and further discussion of these trends is provided in Section 5, which compares actual and predicted path of all these variables.

4 Estimation

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:

$$\ln \mathcal{L}\left(\Theta | K_1^{obs}, B_1^{obs}\right) = \sum_{i=1}^{N} \sum_{t=1}^{T_i} \ln \mathcal{L}_{it}, \tag{11}$$

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

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

In the next subsections I explain the construction of the likelihood contributions, the way that the estimation procedure accounts for the introduction of flexible labor in 1984, and the likelihood function maximization.

4.1 Likelihood contribution

To explain the construction of the individual and period-specific likelihood contributions actually used, it is convenient to describe first how the estimation procedure would be if the theoretical model were used without adding any extra source of randomness. That means that productivity, the only random variable in the model, is responsible for accounting for all the observed variables. If there is no productivity level that matches the four observables, the likelihood contribution would be zero, thus making the whole likelihood function collapse.

In that case, the likelihood contribution for period t (dropping individual subscripts to improve legibility) is

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

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, $t = 1$: The first observations of capital and debt are not predicted by the model, so, as in other panel data estimations, it is assumed that $K_1 = K_1^{obs}$ and $B_1 = B_1$. 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 $K_1, H_0, (1 + r_1) B_1, \theta_1$. However, apart from ignoring θ_1, we ignore H_0 and r_1. Since 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 $L_T^{obs} = L_T(K_T, H_{T-1}, (1 + r_T) B_T, \theta_T)$.

Throughout the construction of each likelihood contribution, apart from accounting for all observables (except for the first observation of capital and debt), we obtain sequences of unobservables: productivities $\{\theta_t\}_{t=0}^{T}$, interest rates $\{r_t\}_{t=1}^{T}$ and rigid labor H_0.

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

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

Hence, a strict condition for the likelihood function not to become zero is that $\widehat{\psi}_t = 1$, for all $t = 1, 2, ..., T$. Having only one source of randomness makes it unlikely to avoid the collapse of the likelihood function. Most likely this likelihood function would collapse, even if the data were generated by the theoretical model, because it would be computed at the wrong parameters. The solutions proposed in the literature consists in adding extra sources of randomness, typically measurement errors, which are introduced in the likelihood computation, not in the theoretical model (Flinn & 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 decreases, the higher 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

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

where σ_K, σ_H, σ_L, σ_B measure the distance between observed and predicted capital, rigid labor, flexible labor and debte, respectively. Thus, this procedure is basically a smoothed version of the estimation without any additional source of randomness in the model. It allows to recover a sequence of predicted variables, observables and unobservables:$\{K_t\}_{t=1}^{T+1}$, $\{B_t\}_{t=1}^{T+1}$, $\{H_t\}_{t=0}^{T}$, $\{L_t\}_{t=1}^{T}$, $\{\theta_t\}_{t=0}^{T}$, $\{r_t\}_{t=1}^{T}$. Any policy analysis of counterfactual conducted once the estimation is done can use the sequence of unobservables to generate alternative sequences of observables. Moreover, if the model is well specified, maximization of the likelihood function shuld lead to $\sigma_K \to 0$, $\sigma_B \to 0$, $\sigma_H \to 0$, $\sigma_L \to 0$, $\widehat{\psi}_t \to 1$ as the estimated parameter set converges to the true one: $\widehat{\Theta} \to \Theta$. Deviations of these measures of distance from zero can be taken as a measure of missspecification.

4.2 The 1984 Labor Market Reform

Because the sample starts in 1983 and ends in 1995, 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

$$\begin{aligned} \text{Regime wihout flexible labor} &: \quad t \leq 1984, \\ \text{Regime with flexible labor} &: \quad t > 1984. \end{aligned}$$

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.

4.3 Likelihood Maximization

The set of parameters to be estimated is $\Theta = \{\alpha, \beta, \delta, \gamma, \lambda, \rho, w_H, w_L, C, F, \phi, \mu, \sigma, \overline{D}, \sigma_K, \sigma_H, \sigma_L, \sigma_B\}$, 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 we performed to solve the theoretical model (see Appendix A4). The likelihood function is maximized using the Powell algorithm (Press, Teutolsky & Vetterling 1992) which uses direction set methods to find the maximum. This algorithm relies on functional evaluations, not gradient methods.

5 Results

5.1 Parameters

Table 2 reports the maximum likelihood parameter estimates and the corresponding asymptotic standard errors. The coefficient of capital is estimated to be about 0.2565, whereas the coefficient of labor is around 0.5053. These Cobb-Douglas parameters display decreasing returns to scale. The fact that γ=0.7357>β =0.5053 indicates complementarity between the two types of labor: more rigid labor implies more flexible labor. The estimate for λ is 0.1950, that is, flexible labor is around 20% as productive rigid labor.

[Insert Table 2 here]

The depreciation parameter for capital of 0.1565 is in line with previous research, whereas the rate of quits of rigid labor is 0.0054. Movement in rigid labor do not rely on quits, but on the firms' decisions. Wage rates of 2.0581 for rigid labor and of 0.6987 for flexible labor correspond respectively to average and minimum wages per annum in Spain. Firing costs are relatively high with respect to observed severance payments, but they have to be interpreted as the total cost the employer has to pay for reducing rigid labor. The riskless interest rate estimated at 4.22% per annum coincides with the observed one during the sample period. The stochastic process of productivity shows an autocorrelation parameter of 0.8826. The lower threshold on dividends is estimated at 100.1094, which is shown to be binding in the next subsection. 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. Given that the asymptotic standard errors are very low, an assessment of the model's ability to fit the data is provided in the next subsections.

5.2 Graphical Comparison

Figure 1 reports the paths for actual and predicted average capital, debt, and rigid and flexible labor assets 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; however, it overpredicts debt in the first years of the sample and it underpredicts it in the last years. This looks clearer in Figure 1c, 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 1d 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 1 here]

5.3 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 build a measure of distance between the observed and the predicted continuous variables. Let the predicted errors be $e = y_{obs} - \widehat{y}$, where y_{obs} is the observed and $\widehat{y}$ is the predicted variable (capital, debt, and the two types of labor).

Squaring and summing across observations, one obtains

$$\sum y_{obs}^2 = \sum \widehat{y}^2 + 2\sum \widehat{y}e + \sum e^2,$$

where, unlike in the linear regression framework, in which $\sum \widehat{y}e = 0$, the 'total sum of squares' $\sum y_{obs}^2$ does not need to coincide with the sum of the explained plus the error sum of squares $\sum \widehat{y}^2 + \sum e^2$. Thus, I use two measures of distance: one is the statistic

$$d_1 = \frac{\sum \widehat{y}^2}{\sum \widehat{y}^2 + \sum e^2},$$

which is between zero and one, and indicates the importance of the error term in comparison with the predicted variable; and the second is the statistic

$$d_2 = \frac{\sum \widehat{y}^2 + \sum e^2}{\sum y_{obs}^2},$$

which is positive but can be smaller or greater than one, and measures the percentage of the variation of the predicted variable and the error as a percentage of the variation of the observed variable. If d_2 is close to one, d_1 can be interpreted as an R^2 statistic, measuring the percentage of the observed variable's variation explained by the model. If d_2 is far from one at either side, this interpretation is not possible; however this statistic informs whether the predicted variable is correlated with the predicted error: if $d_2 < 1$, then $\sum \widehat{y}e > 0$.

[Insert Table 3a and Table 3b here]

Table 3a and Table 3b reports the actual and predicted averages, the χ_t^2 statistics and the two distance statistics d_1 and d_2 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 was clear in the graphical comparison, the model fit for capital and rigid labor is good. The model does not fit the debt data as well as it does with capital and rigid labor, yet the χ^2 statistic falls below the critical value at a 5% of significance, except in year 1986 and 1987. For flexible labor, in spite of the systematic average underprediction of the model, the χ^2 statistic is significant for all years.

With regard to the d_1 statistics, it can generally be interpreted as an R^2 statistic;

in particular, for capital and for rigid labor. At the initial year, the d_1 and d_2 statistics capture also that predicted capital and debt coincide perfectly with their observed counterparts: $d_1 = d_2 = 1$. Capital and rigid labor have a d_1 statistic above 0.95 and a d_2 statistic around one, that is, the model fits these data are fairly well. However, debt exhibits a d_1 as low as 0.5 and a d_2 as ranging between 1.14 and 1.96; and flexible labor presents a d_1 as low as 0.46 and a d_2 ranging between 0.86 and 1.31. Consequently, and as explained above, the model has weaker predicting power with these two variables, though fit improves for flexible labor in the last years of the sample: d_1 increases until reaching 0.89 and d_2 converges to one.

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.

6 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 labor, 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 2.

[Insert Table 4a, Table 4b and Figure 2 here]

6.1 No Flexible Labor

Figure 2a and Figure 2b 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 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 reduce rigid labor substantially.

6.2 No Labor Rigidities

Figure 2c and Figure 2d 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 and hiring costs which are set to zero: $C = F = 0$. 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) reduce debt slowly, and (iii) produce a modest increase in capital. This reaction is a sign that firms have too much rigid labor, which they would like to get rid off and they cannot because of the high costs that this would represent.

6.3 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 low level. As shown in Figure 2e and Figure 2f, this regime change implies (i) a substantial increase in capital accumulation, (ii) a substantial reduction in rigid labor 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 Spanish economy and shows that removing financial constraints creates more employment than only removing labor market rigidities. Actually, once financial constraints are relaxed, removing firing and hiring costs does not produce different trajectories of the four relevant variables. *Eurosclerosis* can persist under imperfect capital markets. A financial liberalization can activate both the sclerotic labor markets as well as increase investment by a big amount.

7 Conclusions

Using a dynamic model of labor demand under liquidity constraints, I showed 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, a regime changes that relaxes financial constraints would produce trends similar to those produced by 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

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

$$G'(r') = 1 - \Phi(\kappa') - \frac{1}{\sigma}\phi(\kappa')(1 + r')\underline{\theta}'_{r'}$$

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

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

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

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.

Discretization of variables

Original variable	Discretized variable	Grid of points	Number of gridpoint	Lower Bound	Upper Bound
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,

[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 $K(0) = B(0) = \widetilde{B}(0) = H(0) = L(0) = 0$.

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. (6) 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. (8) 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. (4) 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. $V_n(k', i', h, s') \geq 0$.

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

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

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 $r' = \frac{(1+\rho)}{g\left(\underline{s}'_0|s\right)} - 1$, 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

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

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

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

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

   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 $k = k(m,s;h)$ for each combination $m, s; h$.

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

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

   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

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

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 $(k_{t+1},j_{t+1},h_t,l_t)=(k',j',h,l)\left(k_t,i_t,h_{t-1},s_t\right)$, and $i_{t+1}=i'\left(k_{t+1},j_{t+1},h_t,s_t\right)$. Using s_{t-1}, compute the likelihood contribution: $\mathcal{L}_t=\widehat{\psi}_t\times g\left(s_t,s_{t-1}\right)$ 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 $(h_T,l_T)=(h,l)\left(k_T,i_T,h_{T-1},s_T\right)$. Using s_{T-1}, compute the likelihood contribution $\mathcal{L}_T=\widehat{\psi}_T\times g\left(s_T,s_{T-1}\right)$.

Once the likelihood contributions are computed, take logs and add them up, that is, compute the likelihood function from Eq. (11).

References

Acemoglu, D. (2001), 'Credit Market Imperfections and Persistent Unemployment', *European Economic Review, Papers and Proceedings* **45**(4-6).

Aguirregabiria, V. & Alonso-Borrego, C. (1999), Labor contracts and flexibility: Evidence from a labor market reform in spain. mimeo. University of Chicago. Universidad Carlos III de Madrid.

Alonso-Borrego, C. & Bentolila, S. (1994), 'Investment and Q in Spanish manufacturing firms', *Oxford Bulletin of Economics and Statistics* **56**, 49–65.

Barlevy, G. (n.d.), Credit Market Frictions and the Reallocation Process. Forthcoming in the *Journal of Monetary Economics*.

Bentolila, S. & Bertola, G. (1990), 'Firing costs and labor demand: How bad is eurosclerosis?', *Review of Economic Studies* **57**, 381–402.

Bentolila, S. & Saint-Paul, G. (1992), 'The macroeconomic impact of flexible labor contracts, with an application to spain', *European Economic Review* **36**, 1013–1053.

Bernanke, B., Gertler, M. & Gilchrist, S. (1999), Credit markets and aggregate fluctuations, *in* J. B. Taylor & M. Woodford, eds, 'Handbook of Macroeconomics', Amsterdam: North Holland.

Cabrales, A. & Hopenhayn, H. (1997), 'Labor market flexibility and aggregate employment volatility', *Carnegie-Rochester Series on Public Policy* **46**, 189–228.

Estrada, A. & Vallés, J. (1995), Inversión y costes financieros: evidencia en España con datos de panel. Banco de España. Servicio de Estudios. Documento de Trabajo No. 9506.

Flinn, C. & Heckman, J. (1982), 'New methods for analyzing structural models of labor force dynamics', *Journal of Econometrics* **188**, 115–68.

Hopenhayn, H. & Rogerson, R. (1993), 'Job turnover and policy evaluation', *Journal of Political Economy* **101**(5).

Jorgenson, D. W. (1963), 'Capital theory and investment behavior', *American Economic Review* **33**, 247–259.

Modigliani, F. & Miller, M. (1958), 'The cost of capital, corporation finance, and the theory of investment', *American Economic Review* **38**, 261–297.

Nickel, S. & Nicolitsas, D. (1999), 'How does financial pressure affect firms?', *European Economic Review* **43**, 1435–56.

Pratap, S. & Rendon, S. (2003), 'Firm investment in imperfect capital markets: A structural estimation', *Review of Economic Dynamics* **6**(3), 513–545.

Rust, J. (1988), 'Maximum likelihood estimation of discrete control processes', *SIAM Control and Optimization* **26**(5), 1006–1024.

Sharpe, S. (1994), 'Financial market imperfections, firms leverage and the cyclicality of employment', *American Economic Review* **84**, 1060–74.

Wasmer, E. & Weil, P. (2002), The Macroeconomics of Labor and Credit Market Imperfections. CEPR Working Paper 3334.

Wolpin, K. (1987), 'Estimating a structural search model: The transition from school to work', *Econometrica* **55**, 801–817.

Table 1: Descriptive Statistics by period and firm size

		Up to 1987			After 1987		
Variable	All	Small	Medium	Large	Small	Medium	Large
Obs.	10787	1244	1299	1293	2869	2812	2819
Capital K							
Average	455	33	167	1126	32	161	1189
St. Dev.	(741)	(20)	(63)	(7114)	(20)	(65)	(954)
K/N	3.18	0.72	1.76	3.37	0.97	2.21	3.84
$\Delta K/K$ %	3.32	0.31	0.93	0.41	1.01	4.22	4.52
Debt B							
Average	207	51	153	445	43	131	434
St. Dev.	(282)	(68)	(180)	(363)	(94)	(165)	(373)
B/N	1.44	1.18	1.70	1.35	1.31	1.80	1.40
B/K	0.45	1.63	0.96	0.40	1.35	0.81	0.36
$\Delta B/B$ %	0.47	-0.78	3.00	-2.40	-1.76	1.87	1.20
Rigid Labor H							
Average	123	40	84	304	27	58	255
St. Dev.	(189)	(35)	(67)	(269)	(22)	(51)	(261)
$\Delta H/H$ %	0.12	-0.07	0.34	-0.06	-1.07	0.21	0.03
Flexible Labor L							
Average	21	4	9	25	6	14	54
St. Dev.	(60)	(11)	(24)	(67)	(9)	(23)	(106)
L/N	0.15	0.08	0.09	0.08	0.17	0.19	0.17
$\%(L=0)$	32.51	55.87	46.50	37.81	34.23	23.66	19.09
$\Delta L/L$ %	6.79	14.02	12.95	26.36	4.60	5.00	3.89
Total Labor N							
Average	144	44	93	328	33	72	309
St. Dev.	(220)	(37)	(69)	(289)	(25)	(58)	(317)
$\Delta N/N$ %	1.06	1.38	1.39	1.65	-0.11	1.11	0.87

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	St. Err.
Production function		
α	0.2565	0.0782
β	0.5053	0.0996
γ	0.7357	0.2292
λ	0.1950	0.1121
Depreciation		
δ_k	0.1565	0.0252
δ_h	0.0054	0.0013
Wages		
w_h	2.0581	0.4777
w_l	0.6987	0.0569
Firing and Hiring Costs		
F	8.8890	0.1532
C	0.1056	0.3325
Riskless interest rate		
ρ	0.0422	0.3293
Stochastic Process		
ϕ	0.8826	0.0978
μ	1.3229	0.2189
σ	2.3338	0.4032
Borrowing Constraint		
$-\overline{D}$	100.1094	7.7664
Variables' Errors		
σ_K	142.96	5.29
σ_B	267.25	19.38
σ_H	40.81	4.25
σ_L	36.15	2.22
Log-Likelihood		
$-\ln \mathcal{L}$		145495.65

Table 3a: Actual and Predicted Variables

Year	Capital Act.	Capital Pre.	Capital χ^2	$\frac{\Sigma K^2}{\Sigma K^2+\Sigma e_K^2}$	$\frac{\Sigma K^2+\Sigma e_K^2}{\Sigma K_{obs}^2}$	Debt Act.	Debt Pre.	Debt χ^2	$\frac{\Sigma B^2}{\Sigma B^2+\Sigma e_B^2}$	$\frac{\Sigma B^2+\Sigma e_B^2}{\Sigma B_{obs}^2}$
1983	597	597	0.00	1.00	1.00	240	240	0.00	1.00	1.00
1984	511	503	1.10	0.99	0.98	258	270	1.57	0.89	1.14
1985	450	452	0.45	0.98	1.01	244	267	6.96	0.71	1.61
1986	401	395	0.81	0.97	1.00	201	238	36.05	0.72	1.75
1987	395	384	0.41	0.97	0.99	187	238	29.25	0.72	1.96
1988	401	388	2.11	0.97	0.98	183	215	12.56	0.67	1.79
1989	423	412	0.40	0.97	1.00	186	217	12.56	0.67	1.82
1990	451	439	0.44	0.97	0.98	204	200	5.26	0.59	1.54
1991	477	460	0.07	0.97	0.96	222	185	10.19	0.55	1.34
1992	475	463	0.13	0.98	0.98	223	182	19.63	0.53	1.29
1993	471	454	0.06	0.98	0.96	210	164	15.85	0.50	1.33
1994	466	456	0.52	0.98	0.98	199	169	8.78	0.52	1.43
1995	485	469	2.50	0.98	0.96	197	169	4.13	0.51	1.53
1996	531	514	2.84	0.98	0.97	198	178	8.77	0.54	1.53
$\sqrt{\frac{\Sigma e^2}{n}}$	126.13					262.38				

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 Act.	Rigid Labor Pre.	Rigid Labor χ^2	$\frac{\Sigma H^2}{\Sigma H^2+\Sigma e_H^2}$	$\frac{\Sigma H^2+\Sigma e_H^2}{\Sigma H_{obs}^2}$	Flexible Labor Act.	Flexible Labor Pre.	Flexible Labor χ^2	$\frac{\Sigma L^2}{\Sigma L^2+\Sigma e_L^2}$	$\frac{\Sigma L^2+\Sigma e_L^2}{\Sigma L_{obs}^2}$
1983	185	184	1.08	0.99	1.00	10	0		0.00	1.00
1984	163	162	0.54	0.99	1.01	11	0		0.00	1.00
1985	148	146	0.22	0.98	1.00	10	6	0.33	0.46	1.31
1986	131	127	4.07	0.98	1.00	12	6	0.50	0.48	1.16
1987	122	119	0.27	0.97	1.02	15	8	0.25	0.63	0.96
1988	118	113	2.14	0.96	1.00	19	10	1.00	0.66	0.97
1989	116	112	1.60	0.96	0.99	25	14	0.50	0.63	0.79
1990	116	112	6.37	0.96	0.99	24	14	0.14	0.70	1.02
1991	116	112	1.90	0.96	0.99	24	14	0.17	0.74	1.07
1992	110	109	1.54	0.95	1.00	26	15	1.00	0.76	0.87
1993	107	107	0.79	0.96	1.01	23	13	0.33	0.75	0.98
1994	105	107	0.23	0.96	1.05	24	13	0.25	0.68	0.86
1995	107	111	0.14	0.95	1.07	26	15	1.00	0.69	0.92
1996	111	115	1.16	0.96	1.03	26	22	0.33	0.89	0.90
$\sqrt{\frac{\Sigma e^2}{n}}$	41.18						35.99			

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					
$-\overline{D}$	$<\infty$				∞		$<\infty$				∞	
C,F	>0		$=0$		≥ 0		>0		$=0$		≥ 0	
L	≥ 0	$=0$	≥ 0	$=0$	≥ 0	$=0$	≥ 0	$=0$	≥ 0	$=0$	≥ 0	$=0$
1983	597	597	597	597	597	597	240	240	240	240	240	240
1984	503	503	503	503	503	503	270	270	270	270	270	270
1985	452	452	452	452	452	452	267	267	267	267	267	267
1986	395	414	431	426	572	504	238	256	191	195	22	22
1987	384	398	383	371	606	520	238	254	128	137	21	21
1988	388	426	407	405	649	568	215	242	102	120	14	14
1989	412	466	425	412	666	582	217	240	90	93	20	20
1990	439	463	483	480	733	641	200	207	91	105	12	12
1991	460	464	495	486	738	637	185	180	83	89	15	15
1992	463	469	501	489	734	634	182	176	80	90	23	23
1993	454	467	493	475	738	630	164	155	66	69	10	10
1994	456	462	492	480	748	639	169	147	58	71	10	10
1995	469	477	511	487	762	655	169	144	62	71	10	10
1996	514	528	571	563	827	708	178	157	83	102	10	10

Table 4b: Regime Changes

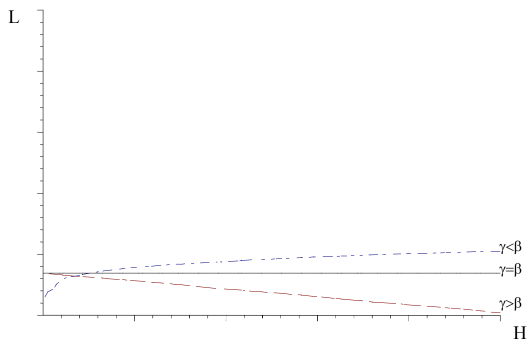
Year	Rigid Labor						Flexible Labor					
$-\overline{D}$	$<\infty$				∞		$<\infty$				∞	
C,F	>0		$=0$		≥ 0		>0		$=0$		≥ 0	
L	≥ 0	$=0$	≥ 0	$=0$	≥ 0	$=0$	≥ 0	$=0$	≥ 0	$=0$	≥ 0	$=0$
1983	184	184	184	184	184	184	0	0	0	0	0	0
1984	162	162	162	162	162	162	0	0	0	0	0	0
1985	146	143	29	33	29	33	6	0	12	0	12	0
1986	127	124	32	34	35	35	6	0	9	0	10	0
1987	119	116	37	39	42	40	8	0	11	0	12	0
1988	113	110	38	43	44	44	10	0	12	0	13	0
1989	112	110	50	52	56	53	14	0	16	0	17	0
1990	112	108	52	56	60	59	14	0	16	0	18	0
1991	112	110	56	59	62	60	14	0	17	0	17	0
1992	109	106	56	60	61	61	15	0	16	0	17	0
1993	107	104	54	56	58	58	13	0	15	0	16	0
1994	107	105	55	57	59	58	13	0	14	0	15	0
1995	111	108	63	64	70	67	15	0	16	0	17	0
1996	115	120	84	86	113	112	22	0	28	0	34	0

Table A1: Structure of the Panel

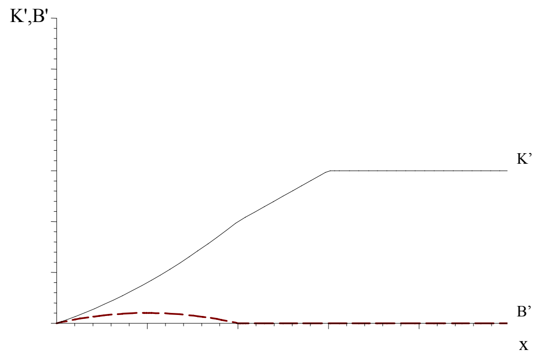
Year	Obs.	Freq.	Cumulative
1983	439	4.07	4.07
1984	568	5.27	9.34
1985	688	6.38	15.71
1986	849	7.87	23.58
1987	964	8.94	32.52
1988	972	9.01	41.53
1989	959	8.89	50.42
1990	910	8.44	58.86
1991	841	7.80	66.65
1992	830	7.69	74.35
1993	767	7.11	81.46
1994	713	6.61	88.07
1995	678	6.29	94.35
1996	609	5.65	100.00
Total	10787	100.00	

Table A2: Balance of the Panel

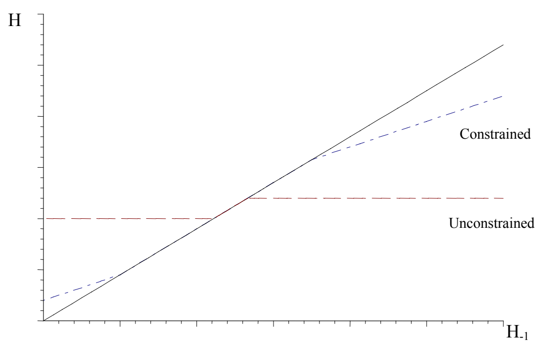
Obs. by firm	Obs.	%	Cum.	Firms	%	Cum.
5	1115	10.34	10.34	223	18.32	18.32
6	1116	10.35	20.68	186	15.28	33.61
7	721	6.68	27.37	103	8.46	42.07
8	864	8.01	35.38	108	8.87	50.94
9	846	7.84	43.22	94	7.72	58.67
10	1000	9.27	52.49	100	8.22	66.89
11	1166	10.81	63.30	106	8.71	75.60
12	852	7.90	71.20	71	5.83	81.43
13	741	6.87	78.07	57	4.68	86.11
14	2366	21.93	100.00	169	13.89	100.00
Total	10787	100.00		1217	100.00	



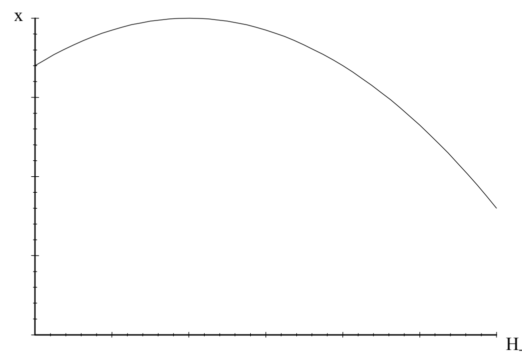
1a: L as a function of H



1b: K' and B' as a function of x



1c: H as a function H_{-1}



1d: x as a function of H_{-1}

Figure 1: Policy Rules for i. Flexible Labor, ii. Capital and Debt, and iii. Rigid Labor; iv. Mapping of H_{-1} on x.

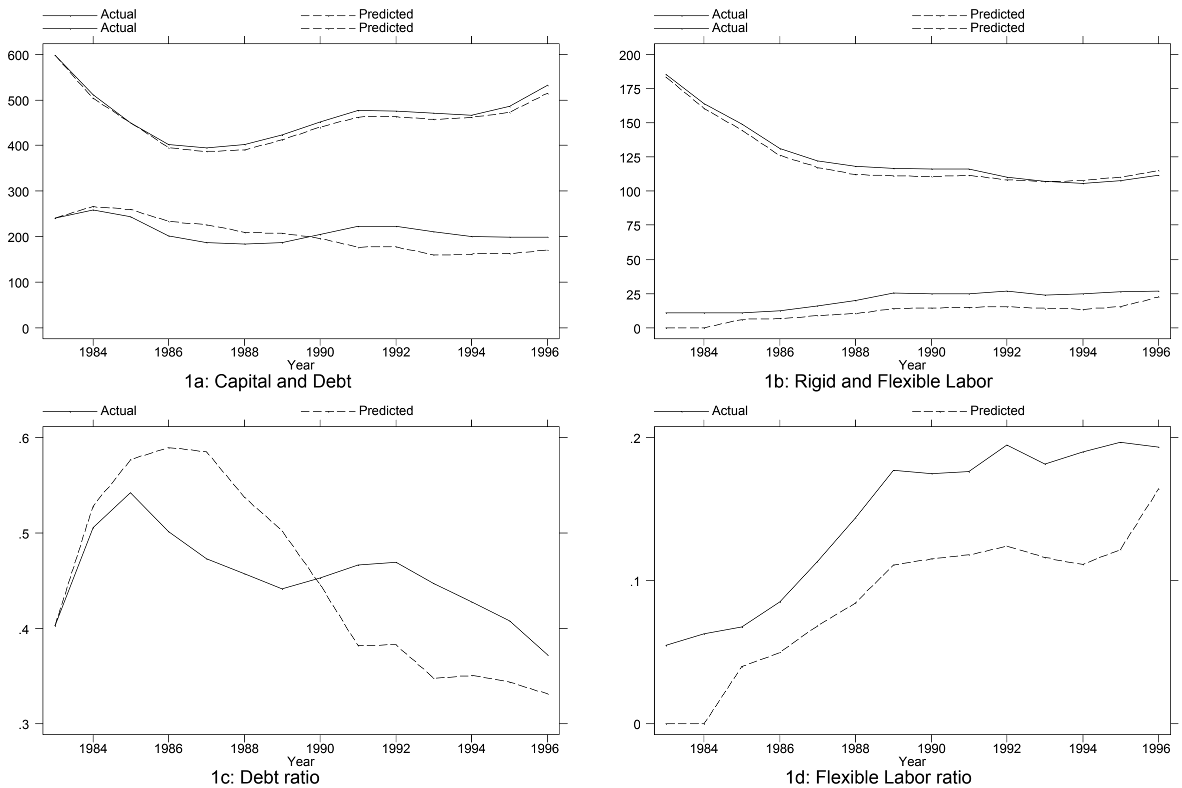


Figure 1: Actual and Predicted Variables

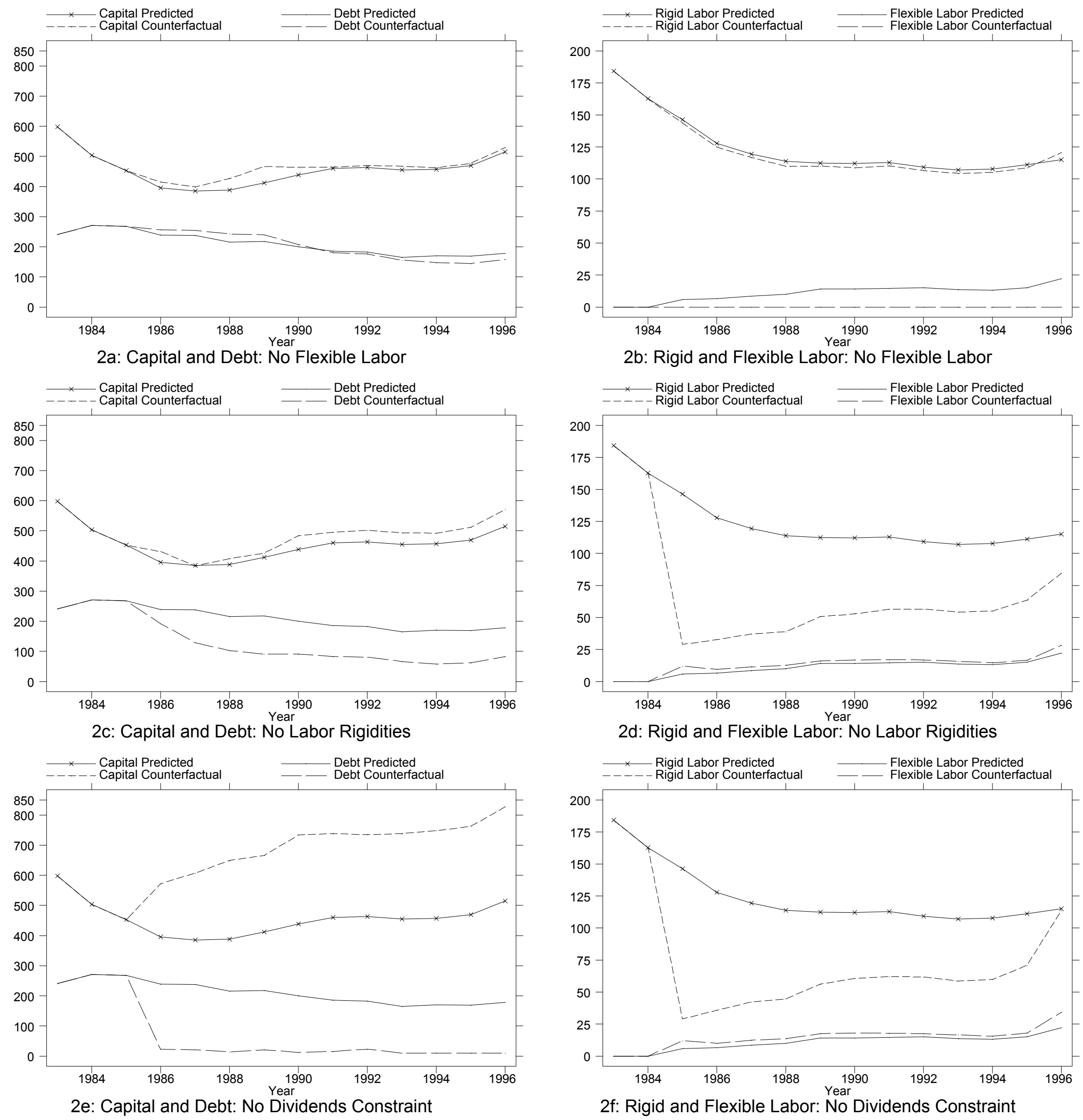


Figure 2: Capital, Debt, and Labor after Regime Changes: (i) No Flexible Labor, (ii) No Labor Rigidities, (iii) No Dividends Constraint