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How Do Firing Costs Affect Innovation and Growth when Workers' Ability is Unknown? Employment Protection as a Burden on a Firm's Screening Process

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Abstract

This paper analyzes the implication of employment protection legislation on a firm's screening process. We present a model in which human-capital-intensive firms (high-tech firms) with imperfect information about their workers' type attempt during a trial period to identify those incompetent workers they will subsequently dismiss. However, employment protection measures place a burden on this screening process thereby motivating innovators to embark on medium-tech projects which are more flexible in their human capital requirements. As such, employment protection legislation distorts the pattern of specialization in favor of medium-tech firms over high-tech firms and consequently slows down the process of economic growth. The results of the paper are consistent with documented data on Europe versus US productivity growth and specialization patterns.

JEL classification: J2, K31, O40, F16

Keywords: Severance Payments, Firing Costs, Screening Costs, Specialization, Growth

1. Introduction

In recent decades, there has been a dramatic rise in US productivity growth accompanied by a remarkable expansion of US human-capital-intensive industries. These trends, however, have been paralleled by different paths in most European countries of lower growth rates and a tendency to specialize in less human-capital-intensive technologies.[3] Several recent theories suggest that the main difference between Europe and the US that might lead to such productivity differences is their labor market policy. These theories argue that employment protection legislations (such as minimum wage laws, unemployment subsidies and mandatory firing costs) that are rarely applied in the US but are extensively used in Europe might have a diminishing effect on productivity and growth.

One theory as presented by Hopenhayn and Rogerson (1993) argues that a tax on job destruction, such as a firing cost, can slow down the reallocation of resources from declining industries to growing industries thereby hampering economic growth by reducing productivity. Another theory raised by Bertola (1994) was that labor mobility costs distort income distribution between labor and capital and therefore reduce investments return and decrease the speed of capital accumulation. Davis and Henrekson (1997) have presented evidence on post war Swedish economy and showed that, among other features, labor market inflexibilities (such as employment security

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[3] See Gordon (2000) Jorgenson and Stiroh (2000), Jorgenson et al (2008), Van Ark et al (2008).

laws and centralized wage bargaining system that compresses wage differentials) distort the industrial distribution of employment, and reduce the output and employment share of smaller, younger and labor intensive firms, thereby hampering the efficient allocation of resources and reducing productivity and economic growth. Saint-Paul (1997 and 2002) proposed that due to innovation risks, employment protection legislation might distort the pattern of specialization in favor of mature goods rather than primary innovation, which negatively affects productivity and growth. Other theories emphasize the effect of labor market regulation on delays and barriers to technology adoption (see Gust and Marquez (2004) and Alesina and Zeira (2006)).

In this paper we attempt to shed light on another channel through which Labor market legislations decrease economic productivity and growth. Namely, this paper focuses on the burden that mandatory firing costs impose on a firm's screening process. We show that high-tech firms with imperfect information about their workers' ability attempt during a trial period to identify those incompetent workers who they will subsequently dismiss. Firing costs stemming from employment protection legislation, however, place a burden on this screening process, thereby motivating innovators to embark on medium-tech projects as they are more flexible in their labor requirements. Employment protection legislation therefore distorts the pattern of specialization in favor of medium-tech firms rather than high-tech firms and consequently slows down the process of economic growth.

The paper presents a model in which a final good is produced by many intermediate goods that can be upgraded in a quality-ladder fashion (see Grossman and Helpman (1991a, 1991b) and Aghion and Howitt (1992)). These intermediate goods, however, are not identical, since they differ in their productivity rates per quality rank and their labor requirements. Specifically:

1) High-tech intermediate goods are much more human-capital-intensive than medium-tech goods, and suffer from lower substitutability between skilled and unskilled workers.

2) Per quality rank, high-tech intermediate goods are much more productive than medium-tech goods and therefore can generate higher economic growth.

An important assumption of the paper is that the workers' type is unknown, and is revealed only after a certain period of employment (which we henceforth term the "trial period"). Following this trial period, both medium-tech and high-tech firms have the opportunity to dismiss any incompetent workers. However, due to differences in labor requirements, only high-tech firms have the incentive to dismiss incompetent workers, whereas medium-tech firms can continue to keep them with no significant loss of profits. Thus, firing costs affect the profit function of high-tech firms significantly more than medium-tech firms and therefore impinge on the decisions of innovators of whether to embark on a high or medium-tech project.

The paper has three central results. First, employment protection legislation and various firing costs that stem from them bias the pattern of specialization from human-capital-intensive products toward less human-capital-intensive products. Second, firing costs can negatively affect productivity growth. In closed economies this negative effect is unambiguous, while in open economies the magnitude of this negative effect depends on a firm's adjustment costs. Third, employment protection might trap the economy into adopting inferior technologies that can affect the trajectory of innovation and growth over a long period of time. A major consequence of this latter result is that measures taken belatedly to reduce firing costs might prove ineffective.

The rest of the paper is organized as follows. Section 2 sets up the basic model. Section 3 relates employment protection legislation to growth. Section 4 extends the basic model. Section 5 discusses the empirical motivation of the model and Section 6 concludes. The mathematical proofs appear in an appendix.

2. The Model

Consider a small open economy whose activities extend over an infinite discrete time. The economy consists of three types of goods: a final good Y that is used for consumption only, and two types of continuum intermediate goods x_i and z_i which we denote by "medium" and "high," respectively. The quality of both the "medium" and "high" intermediate goods can potentially be improved over time in a quality-ladder fashion (see Grossman and Helpman (1991a, 1991b) and Aghion and Howitt (1992)), however, these intermediate goods differ in their improvement rate. Formally, the final good is produced by intermediate goods x_i and z_i in a constant return to scale technology which is given by:

$$Y=\left[\int_0^1\left(\sum_{j=0}^{\kappa_i}\left[\left(\lambda_1(i)\right)^j x_{i,j}\right]\right)^{\sigma} di+\int_0^1\left(\sum_{j=0}^{\kappa_j}[(\lambda_2(i))^j z_{i,j}]\right)^{\sigma} di\right]^{1/\sigma} \tag{1}$$

where $1/(1\text{-}\sigma)$ is the elasticity of substitution between the factors of production which is assumed to be higher than one ($0<\sigma<1$); $x_{i,j}$ ($z_{i,j}$) is the quantity of intermediate good i of types x (type z) of quality j; and $\lambda_1(i)$ and $\lambda_2(i)$ are parameters that reflect the improvement rate of intermediate goods x_i and z_i, respectively.

The final good Y is assumed to be perfectly tradable and its market is perfectly competitive. The intermediate goods, however, are not tradable and their markets are domestic.[4]

To keep the analysis simple and to highlight the effects of interest, several assumptions are used:

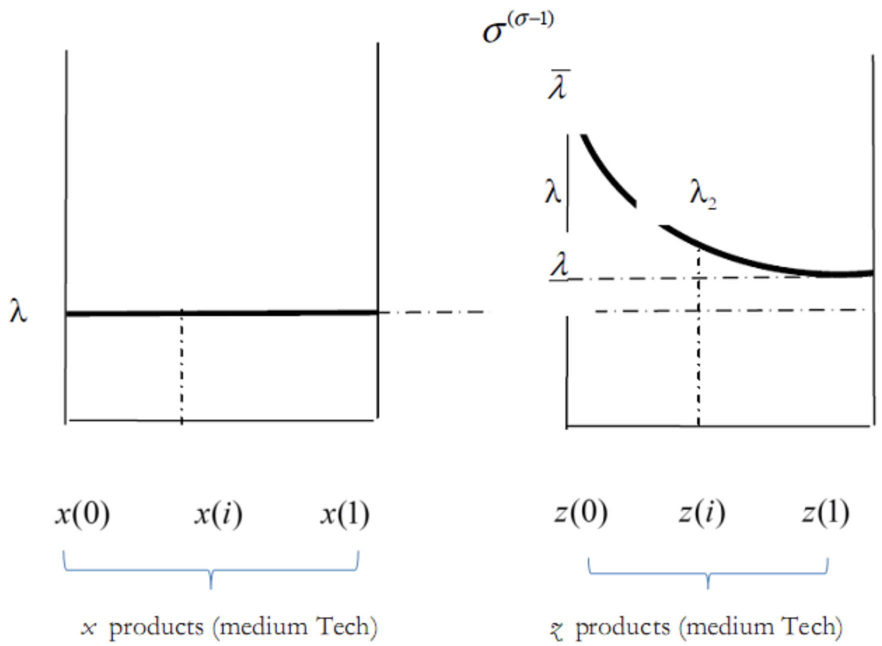
1) High-tech products are much more productive per quality rank than medium-tech products. Formally, the inequality $1<\lambda_1(i_x)<\lambda_2(i_z)$ must hold for any two products i_x and i_z of types x and z.
2) All products of type x have identical quality rank intervals such that λ_1 is constant across intermediate goods of type x.

[4] In section 4 we examine an alternative assumption that intermediate goods are perfectly tradable but due to high adjustment and adoption costs are expensive to import.

3) Intermediate goods of type *z* are located in a decreasing order from the highest to the lowest improvement rate such that $\lambda_2(i_1) \geq \lambda_2(i_2)$ for all $i_1 < i_2$. We henceforth denote $\overline{\lambda} = \lambda_2(0)$ and $\underline{\lambda} = \lambda_2(1)$. We also assume that $\lambda_2(i)$ is a twice-differentiable monotonically non-increasing and weakly convex function of i (i.e., $\lambda_2'(i) \leq 0$ and $\lambda_2''(i) \geq 0$).
4) To reach an equilibrium in which innovators always employ a limit pricing strategy we also assume that $\overline{\lambda} < \sigma^{(\sigma-1)}$.

The quality rank intervals of high-tech and medium-tech products are shown in Figure (1) below.

Figure 1



2.1 Individuals

At each period of time, a generation L of individuals is born. All individuals live for one period only and have identical concave preferences denoted by $u=u(c)$. There are two types of individuals in the economy: a portion $(1-\mu)$ of less-competent individuals and a portion μ of highly-competent individuals $(0<\mu<1)$. Highly-competent individuals are more productive than less-competent individuals when employed in the production process of intermediate goods.

Within the population of competent individuals, there exists a measure $\nu=1$ of individuals who we henceforth refer to as "innovators." It is assumed that innovators are the only individuals in the economy who have the skill to upgrade existing intermediate goods and subsequently to manufacture them. We further assume that each innovator $i \in [0,1]$ is endowed with an idiosyncratic ability parameter $\lambda(i) \in [\underline{\lambda}, \overline{\lambda}]$ that reflects his ability to upgrade high-tech products. Each innovator $i \in [0,1]$ with the ability parameter $\lambda(i)$ is matched to two brands (prototypes) of intermediate goods: an intermediate good x_i of type x and an intermediate good z_i of type z whose improvement rate is given by $\lambda_2(i) = \lambda(i)$. An innovator $i \in [0,1]$ can undertake only one project either of type x or type z, but not both.

One of the most important assumptions of the paper is that members of the economy know, ex-ante, only the probability of being either incompetent or competent (i.e., μ and (1-μ), respectively), however they do not know their own type nor the types of others.[5] During the production process, however, employers can reveal their workers' type as long as they employ them for at least a $0<\beta<1$ unit of time. The sub-period $[0,\beta)$ can therefore be used as a "trial-period" during which employers test their workers and then determine whether they are compatible with their needs.[6]

2.2 Production of Intermediate Goods

All intermediate goods are produced by a linear production function in which labor is the only primary factor. Intermediate goods differ, however, in their labor requirements. We assume that one unit of intermediate good of type x is produced by either one unit of competent workers or $1/\theta$ units of less-competent workers (where $\theta>1$). Intermediate goods of type z, however, differ in their production technology according to whether they were previously or recently upgraded. One unit of an old vintage of the $z_{i,j}$ product can be produced by either one unit of a less-competent or $(1/\theta)<1$ units of competent workers. A state-of-the-art product $z_{i,j}$ *on the other hand can be produced by competent workers only*. The production functions of intermediate goods x and z are given by:

$$x_{i,j} = l_u + \theta \cdot l_s$$

$$z_{i,j} = \begin{cases} l_u + \theta \cdot l_s & \text{if } z_{i,j} \text{ is of an old vintage} \\ \theta \cdot l_s & \text{if } z_{i,j} \text{ is a state-of-the-art product} \end{cases} \tag{2}$$

[5] In section 4 we show that the results of the paper carry through even when this assumption is replaced by the assumption that all individuals know their own type but do not know the types of others (i.e., the information is asymmetric).

[6] In this model we assumed an "ex-post screening process" whereby workers are employed until detected and then are potentially dismissed. An alternative assumption would be that firms implement an "ex-ante screening process" in which workers are screened before employment. The "ex-ante screening process" is naturally less reliable than the "ex-post screening process", but can become more reliable when firms spend more resources on screening. Thus, the higher firing costs are, the higher is the firms' incentive to screen. Thus, both type of screening (ex-ante and ex-post) become more costly when firing costs rise and therefore create a similar (negative) effect on high-tech firms' profit function.

where l_u and l_s are labor inputs of less-competent and competent workers, respectively.

The difference in labor requirements between medium tech and high tech products is a core assumption in our model. It implies that while less-competent workers are totally unproductive in the high-tech sector, competent and less-competent workers are substitutable in the medium-tech sector. Medium-tech producers have therefore no incentive to dismiss less competent workers, while high-tech producers want to dismiss incompetent workers, once detected.[7]

2.3 Equilibrium

We start our analysis by describing how wages are determined. During the trial period, all workers (competent as well as incompetent) are paid in equilibrium a salary w_u which is exactly the marginal productivity of incompetent workers. When the worker type is revealed, however, the salary of competent workers (who can now be identified) becomes θw_u, while the salary of incompetent workers remains w_u. We also assume that competent workers have a sufficient bargaining power to demand a full compensation for the loss of their income $[\beta(\theta\text{-}1)w_u]$ caused by the inability of their employers to identify them during the trial period $[0,\beta)$.[8] We assume that workers who were dismissed from their high-tech jobs do not bear frictional searching costs and they immediately find an alternative job in the medium tech sector.[9]

Let the final good Y serve as a numeraire. Profit maximization by firms, who produce the final good leads to the following first-order condition:

$$p(x_{i,j}) = \frac{\partial Y}{\partial x_{i,j}} = \left(\frac{Y}{x_{i,j}}\right)^{1-\sigma} (\lambda_1)^{\sigma j}$$

$$p(z_{i,j}) = \frac{\partial Y}{\partial z_{i,j}} = \left(\frac{Y}{z_{i,j}}\right)^{1-\sigma} \left(\lambda_2(i)\right)^{\sigma j} \tag{3}$$

where $p(x_{i,j})$ and $p(z_{i,j})$ are the prices of intermediate goods of type $x_{i,j}$ and $z_{i,j}$ respectively. We assume that old-vintage technology can be instantly and costlessly adopted by competitive firms while the state-of-the-art technology can be adopted only after one period of time. This assumption implies that innovators who recently upgraded an

[7] The specific production functions in equation (2) are chosen for simplicity only. The results of the paper carry through with other production functions in which less-competent and highly-competent workers exhibit significantly higher substitutability in medium-tech than high-tech products.

[8] This assumption does not affect the results of the paper, but it does significantly simplify the innovators' profit functions.

[9] In section 4 we relax this assumption and show that the results of the paper still hold even when workers who were dismissed bear a certain level of frictional searching costs.

intermediate good become monopolistic producers for one period only, and then are replaced by competitive firms.

At each period of time t, final good producers can purchase intermediate goods from both competitive as well as monopolist producers. In the case where intermediate goods $x_{i,j}$ and $z_{i,j}$ are purchased from competitive firms, their competitive prices must be equal to their constant marginal costs (i.e., $p(x_{i,j}) = p(z_{i,j}) = w$). If, however, the intermediate goods $x_{i,k(i)}$ and $z_{i,k(i)}$ are purchased from monopolistic innovators (who just tapped the state-of-the-art products), then final good firms will be willing to pay a premium for these products as long as their prices are not higher than $\lambda_1 \cdot p(x)$ and $\lambda_2(i) \cdot p(z_i)$, respectively. Innovators who own the monopolistic firms, would clearly not charge prices below these prices. Thus, the monopolistic prices are given by:[10]

$$\begin{aligned} p(x) &= \lambda_1 w \\ p(z_i) &= \lambda_2(i) w \end{aligned} \tag{4}$$

where w is the real wage of unskilled workers. By substituting equation (4) into equation (3), we get the demand functions of final good producers for products x and z:

$$\begin{aligned} x_{i,j} &= Y \frac{\lambda_1^{(j\frac{\sigma}{1-\sigma})}}{(w\lambda_1)^{\frac{1}{1-\sigma}}} \\ z_{i,j} &= Y \frac{\lambda_2(i)^{(j\frac{\sigma}{1-\sigma})}}{(w\lambda_2(i))^{\frac{1}{1-\sigma}}} \end{aligned} \tag{5}$$

We now describe how innovators rank intermediate goods in terms of profits. In order to focus on the role of incomplete information in the allocation of resources, and to disentangle other effects (such as differences in R&D risks as in Saint-Paul (1997) and (2002)), we assume that all innovators can ensure the success of the innovation process by carrying-out some R&D activities that cost $\overline{G}$ units of the final good Y. $\overline{G}$ is assumed to be very small and identical to all innovators in all sectors.

Suppose that at the beginning of some period t, an innovator considers whether to operate in the high-tech or the medium-tech sector. If the innovator decides to operate in the medium-tech sector then his profit function is given by:

[10] The assumption that $1 < \lambda_1 < \lambda_2(i) < \sigma^{(\sigma-1)}$ implies that firms who produce the state-of-the-art products (leaders) always employ a limit-pricing strategy. Under an alternative condition that $w\sigma^{(\sigma-1)} < \lambda_1 < \lambda_2$, innovators would set a price which is not lower than $w\sigma^{(\sigma-1)}$. The assumption that $\lambda_1 < \lambda_2 < \sigma^{(\sigma-1)}$, however, ensures that monopolistic prices can never be reached and instead the innovators can set a price that is sufficiently below the monopoly price so as to make it just slightly unprofitable for potential producers of the last version of the product.

$$\pi(x) = xw(\lambda_1 - 1) - \overline{G} \tag{6}$$

If, on the other hand, he decides to operate in the high-tech sector (i.e., to produce a state-of-the-art product of type *z*), then he cannot detect, at least not during the trial period $[0,\beta)$, whether the workers he hires are productive or not. Thus, he hires workers of whom only portion μ are productive. Under such conditions, he can either dismiss the unproductive workers when he detects them (after a $[0,\beta)$ sub-period of time) and bear the mandatory firing costs, or he can continue hiring them throughout the production process while bearing the costs of paying them salaries. The profit functions under each alternative path are given by:[11]

$$\Pi_z^f(F) = zw\left[(\lambda_2(i) - 1) - \beta(1+F)\frac{(1-\mu)}{\mu\theta}\right] - \overline{G}$$

$$\Pi_z^d = zw\left[(\lambda_2(i) - 1) - \frac{(1-\mu)}{\mu\theta}\right] - \overline{G} \tag{7}$$

where $\Pi_z^f(F)$ *and* Π_z^d are the innovator's profits under each alternative path (i.e., fire, do-not fire, respectively) and F is a mandatory rate of severance pay as a portion of wage that employers must compensate dismissed employees. Note that mandatory firing costs, if they exist, appear only in the profit function of high-tech firms' and therefore only innovators who operate in the high-tech sector might be motivated to dismiss workers. The following lemma relates mandatory firing costs to operating profits in the high-tech sector.

Lemma 1:

(i) *Whenever the mandatory firing cost F is lower than $\frac{(1-\beta)}{\beta}$, innovators who upgrade and produce a state-of-the-art product of type z would rather dismiss unproductive workers than continue to hire them. If, however, F>$\frac{(1-\beta)}{\beta}$, innovators who upgrade and produce a state-of-the-art product of type z would rather continue to hire unproductive workers than dismiss them.*

[11] Innovators may use another screening process in which they test workers before they are employed. It is easy to see that this "ex-ante screening process" is equivalent to the "ex-post screening process" assumed above. The higher the firing costs F are, the more reliable is the required screening process and the higher are the firms' outlays. Thus, both type of screening (ex-ante and ex-post) become more costly when firing costs rise and therefore create a similar (negative) effect on the profit functions of high-tech firms.

(ii) *For any product i of type z such that* $\lambda_2(i) > \frac{1+\mu(\theta-1)}{\mu\theta}$*, operating profits are positive for all possible mandatory firing costs F.*

(iii) *For any product i of type z, such that* $\frac{\beta+\mu(\theta-\beta)}{\mu\theta} < \lambda_2(i) < \frac{1+\mu(\theta-1)}{\mu\theta}$*, there exists a threshold value* $\bar{f}(i) = \dfrac{(\mu\theta)\lambda_2(i) - (\beta + \mu(\theta-\beta))}{\beta(1-\mu)}$ *such that any mandatory firing cost* $F > \bar{f}(i)$ *necessarily leads to negative operating profits.*

Proof: The proof follows immediately from equation (7).

Innovators' profit functions in each sector as given in equations (6) and (7) allow us also to establish the conditions under which innovators rank a certain z_i-project either higher or lower than x-projects. Obviously, these ranking conditions also depend on the mandatory firing cost F. The following Lemma states these conditions:

Lemma 2: *Suppose that* $1 < \lambda_1 < \lambda_2(i) < 1 + \frac{1-\mu}{\mu\theta}$*, and that at period t-1, the quality rank of all products of type x is* (j_x-1)*. Then, for any product i of type z with quality rank* $(j_{z_i} - 1)$*, there exists a threshold value:* $\bar{\bar{f}}(i) = \min\left\{ \frac{(\lambda_2(i)-1)}{\beta(\frac{1-\mu}{\mu})} - \frac{(\lambda_1-1)[\lambda_2(i)]^{(\frac{1}{1-\sigma})}\cdot(\lambda_1)^{[(\frac{\sigma}{1-\sigma})j_x]}}{[\lambda_1]^{(\frac{1}{1-\sigma})}(\lambda_2(i))^{[(\frac{\sigma}{1-\sigma})\cdot j_z]}\cdot\beta(\frac{1-\mu}{\mu})} - 1 \,,\, \frac{1-\beta}{\beta} \right\}$

such that whenever the mandatory firing cost F is higher than $\bar{\bar{f}}(i)$*, innovators rank the x projects higher than project* z_i *(i.e.,* $\Pi_z^f(F) < \pi(x)$*) (and vice versa - whenever the mandatory firing cost F is lower than* $\bar{\bar{f}}(i)$*, innovators rank the* z_i *project higher than the x projects (i.e.,* $\pi(x) < \Pi_z^f(F)$*)).*

Proof: By substituting equation (5) into the profit functions (6) and (7) we get that: (*i*) if $1 < \lambda_1 < \lambda_2(i) < 1 + \frac{1-\mu}{\mu\theta}$. Then whenever $F \geq \frac{(1-\beta)}{\beta}$, x projects are always more lucrative than z projects, and (*ii*) if $F < \frac{(1-\beta)}{\beta}$ and $F < \bar{\bar{f}}(i)$ then project z_i is more lucrative than projects of type x.

Note that since the innovators' profits depend on the quality rank of the product they are updating and producing, the threshold value $\bar{\bar{f}}(i)$ must increase with the incipient quality rank of products z (j_z), and must decrease with j_x.

Lemma 3: $\bar{f}(i)$ *and* $\bar{\bar{f}}(i)$ *are non-increasing functions of i.*

Proof: It easy to see that since $\lambda_2'(i) \leq 0$, the functions $\bar{f}(i)$ *and* $\bar{\bar{f}}(i)$ must satisfy $\dfrac{\partial \bar{f}(i)}{\partial(i)} \leq 0$ and $\dfrac{\partial \bar{\bar{f}}(i)}{\partial(i)} \leq 0$.

We now examine how mandatory firing costs affect specialization. Let $X_t \subseteq [0,1]$ and $Z_t \subseteq [0,1]$ denote the sets of intermediate goods of type *x* and *z*, respectively, that innovators upgrade and produce at period *t*. Since intermediate goods of type *z* are ordered from the highest to the lowest improvement rate, and since innovators always prefer to be engaged in the most rewarding projects, then the set Z_t must be either an empty or a closed interval of the form $Z_t = [0, \hat{z}_t]$.[12] Note that the set X_t need not be path-connected. However, since all projects in X_t are equally rewarding, we can assume, with no loss of generality, that the set X_t, if nonempty, is always a closed interval of the form $[0,a]$.

Definition 1: *Let A and B be two economies with an identical number of innovators* ν. *Economy A is said to be more specialized in high-tech projects than economy B if* $X_t(A) \subset X_t(B)$ *and* $Z_t(A) \supset Z_t(B)$.

We now show that high mandatory firing costs bias the pattern of specialization toward medium-tech products. We start our analysis with the following definition and notations.

Definition 2: *For a given firing cost F:*

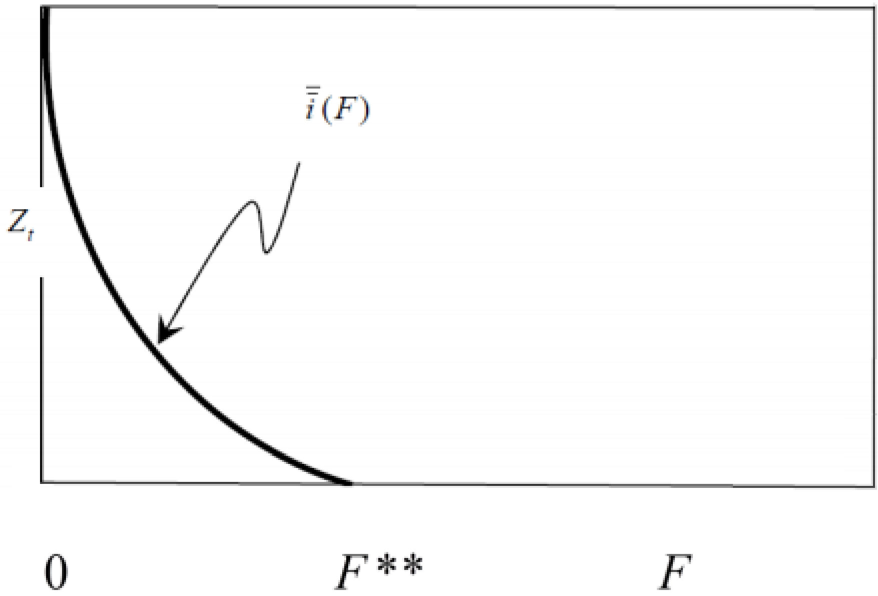
1) *Let* $\bar{\bar{i}}(F)$ *denote the lowest index i of intermediate goods of type z that is ranked either higher than or equal to the most profitable projects of type x. Formally:* $\bar{\bar{i}}(F) = \bar{\bar{f}}^{-1}(F)$.[13]
2) *Let F** denote the lowest mandatory firing cost such that* $\bar{\bar{i}}(F^{**}) = 0$.

The point *F*** as well as the threshold condition expressed by the function $\bar{\bar{i}}(F)$ are shown in Figure 2.

[12] If the set Z_t is nonempty and $i \in Z_t$ then every intermediate good *j* of type *z* such that $j<i$ must also belong to the set Z_t.

[13] The function $\bar{\bar{i}}(F) = \bar{\bar{f}}^{-1}(F)$ can be considered as the marginal index of products z that makes innovators indifferent between project x and project zi.

Figure 2



Lemma 4*:* *If the quality rank of high and medium tech goods are identical (i.e., $j_x=j_z$), then, the set Z_t and X_t are uniquely determined by the function $\bar{\bar{i}}(F)$ such that:*

$$Z_t(F)=\begin{cases} [0,1] & \text{if} \quad \bar{\bar{i}}(F)=1 \\ \left[0,\bar{\bar{i}}(F)\right] & \text{if} \quad \bar{\bar{i}}(F)\le 1 \ \text{and} \ F<F^{**} \\ \phi & \text{if} \quad F\ge F^{**} \end{cases}$$

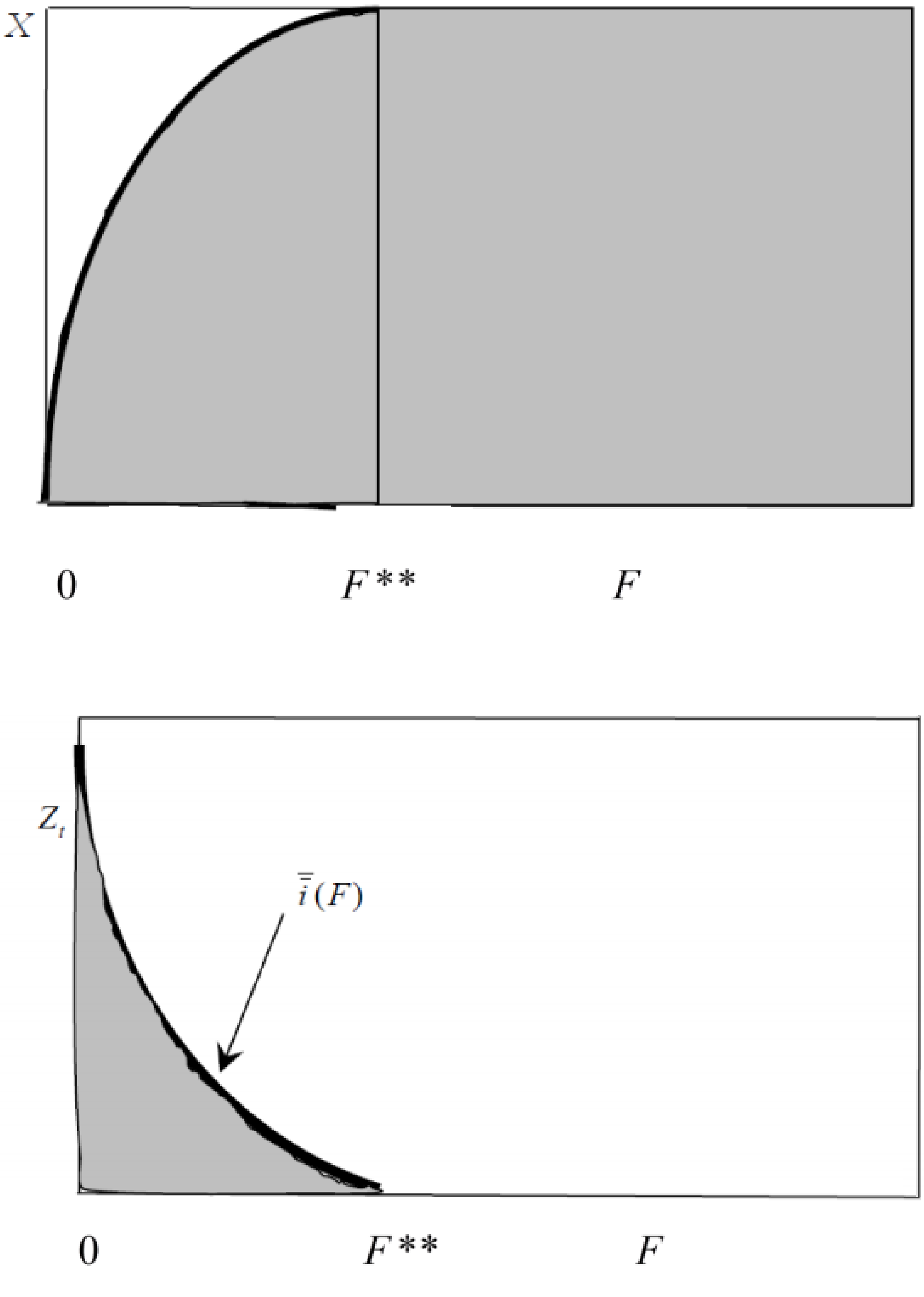
and

$$X_t(F)=\begin{cases} \phi & \text{if} \quad \bar{\bar{i}}(F)=1 \\ \left[0,1-\bar{\bar{i}}(F)\right] & \text{if} \quad \bar{\bar{i}}(F)\le 1 \ \text{and} \ F<F^{**} \\ [0,1] & \text{if} \quad F\ge F^{**} \end{cases}$$

An immediate consequence of Lemma 4 is the following fundamental result.

Proposition 1: *Whenever $j_x=j_z$, high mandatory firing costs bias the pattern of specialization toward medium-tech products. Namely, the inclusion relations $X_t(F_1)\subseteq X_t(F_2)$ and $Z_t(F_1)\supseteq Z_t(F_2)$ hold for any two mandatory firing costs F_1 and F_2 such that $F_1<F_2$.* See Figure 3 below.

Figure 3



Until now we have shown that high firing costs bias the pattern of specialization toward medium-tech products. We now show that high firing costs may also, under certain conditions, create technological traps. Specifically, if a policy of firing-cost-reduction is adopted too late, it will be ineffective in shifting innovators from medium to high-tech projects. To demonstrate this phenomenon, let us assume, for example, that due to high firing costs, a certain economy has specialized in medium-tech products for a significant period of time. The quality rank of products that innovators persistently developed and produced therefore grew, while the quality rank of high-tech projects that were previously abandoned stagnated. Under such conditions, innovators' profits in high-tech products become significantly lower than the already developed and produced products (even with zero firing costs) and therefore innovators do not shift their specialization pattern.

Proposition 2: *Suppose that after some period t>0, the mandatory firing cost F is reduced to zero. If t>0 is sufficiently high, then the reduction of F will not shift specialization toward high-tech products.*

Proof: See Appendix A-1.

To complete the equilibrium analysis, we briefly describe how real wages and aggregate output are determined (the calculations are presented in appendix A-2). Suppose that $\hat{m}$ innovators operate in the medium-tech sector while $\hat{h}$ innovators operate in the high-tech sector. Suppose also that in a certain period *t*, the quality ranks of the state-of-the-art products in the medium and high tech sectors are j_x and j_z, respectively. By substituting equation (5) and the parameters $\hat{m}, \hat{h}, j_x, j_z$ into equation (1) we get the equilibrium wage rates:[14]

$$w_u = \left[\hat{m} \left(\frac{(\lambda_1)^{\frac{1}{1-\sigma} j_x}}{\lambda_1^{\frac{1}{1-\sigma}}} \right)^{\sigma} + \int_0^{\hat{h}} \left(\frac{(\lambda_2(i))^{\frac{1}{1-\sigma} j_z}}{\lambda_2(i)^{\frac{1}{1-\sigma}}} \right)^{\sigma} di \right]^{\frac{1-\sigma}{\sigma}}$$

$$w_s = \theta w_u \tag{8}$$

Then, from equations (1), (5) and (8) we get that the final good output over an individual's lifetime, which is divided between being on probation and after, is given by:[15]

[14] Note that the CRS property of the production technology as well as the linearity property of intermediate goods' production technology ensures that the equilibrium wage rate w_u does not depend on labor supply nor on output. Thus, equilibrium wage rates w_u and w_s are not affected by the movement of incompetent workers from the high to the medium-tech sector at time β.

[15] Note that if $\hat{m} > 0$ and $\hat{h} > 0$, then aggregate production of the final good Y must rise after the trial period $[0,\beta)$ since unskilled workers, who were totally unproductive in the high tech sector during $[0,\beta)$, are dismissed and then start working in the medium tech sector where they become productive.

$$Y=\begin{cases}\dfrac{\left[\hat{m}\left(\left(\lambda_1\right)^{\frac{j-1}{1-\sigma}}\right)^{\sigma}+\int_0^{\hat{h}}\left(\left(\lambda_2(i)\right)^{\frac{j-1}{1-\sigma}}\right)^{\sigma}di\right]^{1/\sigma}}{\left[\frac{\hat{m}}{(1-\mu)+\mu\theta}\left(\lambda_1\right)^{\frac{\sigma j-1}{1-\sigma}}+\frac{1}{\theta\mu}\int_0^{\hat{h}}\left(\lambda_2(i)\right)^{\frac{\sigma j-1}{1-\sigma}}di\right]}\overline{L} & [0,\beta) \\ \\ \dfrac{\left[\hat{m}\left(\left(\lambda_1\right)^{\frac{j-1}{1-\sigma}}\right)^{\sigma}+\int_0^{\hat{h}}\left(\left(\lambda_2(i)\right)^{\frac{j-1}{1-\sigma}}\right)^{\sigma}di\right]^{1/\sigma}}{\left[\frac{\hat{m}}{(1-\mu)+\theta\alpha}\left(\lambda_1\right)^{\frac{\sigma\cdot j-1}{1-\sigma}}+\frac{1}{\theta}\int_0^{\hat{h}}\left(\lambda_2(i)\right)^{\frac{(\sigma j)-1}{1-\sigma}}di\right]}\overline{L} & [\beta,1]\end{cases} \tag{9}$$

3. Macroeconomic Applications

To demonstrate how employment protection legislation affects economic performance we compare between two economies, one with high mandatory firing costs and the other with low mandatory firing costs. We perform our analysis under two alternative assumptions. One is that intermediate goods are not tradable and their markets are therefore domestic, and the other that intermediate goods are tradable, but final good producers face high adjustment costs when purchasing new intermediate goods from abroad. We assume that:

(*A*-1) There exist two economies *A* and *B* with identical population size $\overline{L}$ and identical number of innovators v=1.

(*A*-2) Both economies are launched at period t=0, such that the quality ranks of intermediate goods in both economies at period t=0 is $j=j_x=j_z=0$.

(*A*-3) The mandatory firing cost in economies *A* and *B*, denoted by F_A and F_B, are such that $0 < F_A < F_B < \frac{1-\beta}{\beta}$.

Assumptions (A-1)-(A-3) as well as Lemma 4 and Proposition 1 guarantee that economy *A* is more specialized in high-tech products (type z) than economy *B*, and that this pattern of specialization persists throughout all periods of time. Under these conditions, economy *A* must produce higher levels of output and grow faster than economy *B*. Furthermore, since equation (8) implies that wage rates are positively affected by the volume of high-tech products, wages in economy *A* are higher and grow faster than in economy *B*. Thus:

Proposition 3: *Output and wage rates in an economy with low firing costs (i.e., economy A) are higher and grow faster than in an economy with high firing costs (i.e., economy B).*

Proof: see Appendix A-1.

The results in Proposition 3 follow from our assumption that intermediate goods are not tradable. If we relax this assumption then final good producers from both economies can import new intermediate goods from abroad. Obviously, under such conditions, Proposition (3) need not hold, and economies *A* and *B* will grow at similar rates. However, it is more reasonable to assume that while producers can potentially expand their product variety, they cannot import new intermediate goods immediately, but rather only after a time lag. Specifically, in order to import *new* product x_i or z_i with quality rank k_i from abroad it takes $\Delta t_i = f(k_i)$ periods of time where $\Delta t_i = f(k_i)$ is a non-decreasing function of k_i.[16] It is easy to see that under such conditions, economy *A* grows faster than economy *B,* at least for some periods of time. This delay in technology adoption is well documented in the literature (see, for example, Comin and Hobijn (2004)).

A plausible trade-growth dynamics for economies *A* and *B*, which might, at least to some extent, explain the difference between US and European trade-growth patterns from the mid 1980s until early 2000 is that previous to some period $t=T$ all intermediate goods are of type x only. At period $t=T$, however, new technologies which allow innovators to develop intermediate goods of type z, emerge. The emergence of these new types of intermediate goods is analogous to the general purpose technologies products that appeared in the early 1980s (such as the ICT products) mostly in the US but at a lower pace in Europe (see OECD (2003) for a survey).

Let economies *A* and *B* represent the US and Europe, respectively. Suppose that firing costs in economy *A* are lower than in economy *B*, and that the parameters F_A, F_B and *T* (the period at which the new technologies emerge) are such that the conditions in proposition (1) hold. Innovators in economy *A*, who face low firing costs, become biased toward high-tech intermediate goods projects (and therefore embark on z-projects), while innovators in economy *B* who face relatively high firing costs continue to be engaged in medium-tech projects only. This change in the pattern of project selection affects growth and trade. Final good producers in economy *B* import high-tech products from producers in economy *A*, while final good producers in economy *A* import medium-tech products. Note, however, that since final good producers in economy *A* have already used x products (before period *T*) they do not face any adjustment costs when importing x products from economy *B*, while final good producers in economy *B* are required to adjust to the new z-products they import from economy *A*. Since this adjustment is costly, importation of z-products from economy A is not immediate, but involves a time lag. Economy *A* thereby grows at a higher rate than economy *B*, while growth rates in economy *B* converge to that of economy *A*.

[16] $\Delta t_i = f(k_i)$ represents technology adoption cost in terms of time.

4. Extensions of the Basic Model

In the basic model we made two restrictive assumptions. The first was that all individuals are symmetrically uninformed about their type (i.e., they do not know their own type nor the type of others), and the second assumption was that workers who were dismissed from their job immediately find an alternative job and therefore do not bear frictional (searching) costs. In this section we show that the results of the paper carry through even when these two assumptions are relaxed. To adjust the basic model to this new setting, we assume that:

- All individuals have a constant relative risk aversion utility function (i.e., $u(c)=\frac{1}{1-\gamma}c^{(1-\gamma)}$ where $\gamma>0$).
- The production function of intermediate goods is given by: $x_{i,j}=l_u+\theta_1\cdot l_s$

$$z_{i,j}=\begin{cases} l_u+\theta_1\cdot l_s & \textit{if } z_{i,j} \text{ is of an old vintage} \\ \theta_2\cdot l_s & \textit{if } z_{i,j} \textit{ is a state-of-the-art product} \end{cases} \tag{2'}$$

  where l_u and l_s are labor inputs of less competent and competent workers, respectively, and $1<\theta_1<\theta_2$ (i.e., competent workers are more productive in the high-tech firms than in the medium-tech firms).[17]
- All individuals who are dismissed from their job lose a portion $0<d<1$ of their salaries ($d\cdot w$).[18]
- Subsequent to the trial period $[0,\beta)$, employers can correctly identify the type of their workers with probability $(1-\varepsilon)$ and misidentify them with probability $\varepsilon>0$ (ε is assumed to be relatively small and is common knowledge among all individuals).

We also assume that $\varepsilon>0$ is, on the one hand, small enough to ensure that all competent individuals would be willing to risk working in the high-tech firms but, on the other hand, is sufficiently high to ensure that incompetent individuals would also be willing to risk working in the high-tech sector. Specifically:[19]

[17] The modification we made to the intermediate goods' production function (equation (2')) in conjunction with the subsequent assumptions ensure that all workers (competent as well as less-competent ones) prefer to work in high-tech firms rather than medium-tech firms.

[18] This is a simple way of modeling frictional costs of workers who were fired and search for a new job. The parameter d can be regarded as the average time that workers need to spend on finding a new job and $d\cdot w$ is their total income loss.

[19] In order to ensure that less competent workers will always prefer working in the high-tech firms the parameters d,ε must satisfy: $(1-\varepsilon)u(w)+\varepsilon u(w\theta_1)<(1-\varepsilon)u(w(1-d))+\varepsilon u(w\theta_2)$. And to

$$\frac{u(1)-u((1-d)}{u(1)-u((1-d))+u(\theta_2)-u(\theta_1)} < \varepsilon < \frac{u(\theta_2)-u(\theta_1)}{u(1)-u((1-d))+u(\theta_2)-u(\theta_1)}$$

We now adjust the innovators' profit functions (6) and (7) to the new assumptions of asymmetric information and frictional costs. The profit that innovators can gain in the *x* sector is:

$$\pi_x = xwc(\lambda_1 - 1) - G \tag{6'}$$

where $c = \frac{[(1-\varepsilon)\mu\theta_1+\varepsilon(1-\mu)\theta_1+(1-\varepsilon)(1-\mu)+\varepsilon\mu]}{[\theta_1\cdot\mu+(1-\mu)]}$, and the profit that innovators can gain in the *z* sector is:

$$\pi_{z_i} = \begin{cases} wz\left[\left[\lambda_2(i)c-b\right]-\beta(1+F)\dfrac{\left[(1-\mu)(1-\varepsilon)+\varepsilon\mu\right]}{\theta_2\mu}\right]-G & \textit{dismiss} \\ \\ wz\left[\left[\lambda_2(i)c-b\right]-\dfrac{\left[(1-\mu)(1-\varepsilon)+\varepsilon\mu\right]}{\theta_2\mu}\right]-G & \textit{do not dismiss} \end{cases} \tag{7'}$$

where $b = 1+\frac{\varepsilon(1-\mu)}{\mu(1-\varepsilon)}$.

Lemmas 1 and 2 in the basic model can be easily adjusted to the new profit functions as follows.

Lemma 1':

(i) *Whenever the mandatory firing cost F is lower than $\frac{(1-\beta)}{\beta}$, innovators who upgrade and produce a state-of-the-art product of type z would rather dismiss unproductive workers than continue to hire them. If, however, F>$\frac{(1-\beta)}{\beta}$, innovators who upgrade and produce a state-of-the-art product of type z would rather continue to hire unproductive workers than to dismiss them.*

(ii) *For any product i of type z such that $\lambda_2(i) > \frac{b\theta_2\mu+[(1-\mu)(1-\varepsilon)+\varepsilon\mu]}{c\mu\theta_2}$, operating profits are positive for all possible mandatory firing costs F.*

ensure that competent workers will always prefer working in the high-tech firms the parameters d,ε must satisfy: $(1-\varepsilon)\cdot u(\theta_1 w)+\varepsilon\cdot u(w) < (1-\varepsilon)\cdot u(\theta_2 w)+\varepsilon\cdot u(w(1-d))$.

(iii) *For any product i of type z, such that* $\frac{b+\beta[(1-\mu)(1-\varepsilon)+\varepsilon\mu]}{c\mu\theta_2} < \lambda_2(i) < \frac{b\theta_2\mu+[(1-\mu)(1-\varepsilon)+\varepsilon\mu]}{c\mu\theta_2}$, *there exists a threshold value* $\bar{f}(i) = \dfrac{\lambda_2(i)c - b}{\beta\left[\frac{(1-\mu)(1-\varepsilon)+\varepsilon\mu}{\theta_2\mu}\right]} - 1$ *such that any mandatory firing cost* $F > \bar{f}(i)$ *necessarily leads to negative operating profits.*

Lemma 2': *Suppose that* $1 < \lambda_1 < \lambda_2(i) < \frac{b\theta_2\mu+[(1-\mu)(1-\varepsilon)+\varepsilon\mu]}{c\mu\theta_2}$, *and that at period t-1, the quality rank of all products of type x is (j_x-1). Then, for any product i of type z with quality rank* $(j_{z_i} - 1)$, *there exists a threshold value*

$$\bar{\bar{f}}(i) = \min\left\{\frac{A}{B} - 1 \quad , \frac{1-\beta}{\beta}\right\}$$

where

$$A = \theta_2\mu\left(\lambda_2(i)\right)^{\frac{1}{1-\sigma}}\left\{\left[\lambda_2(i)c - b\right]\frac{(\lambda_2(i))^{\frac{\sigma j_z}{1-\sigma}}}{(\lambda_2(i))^{\frac{1}{1-\sigma}}} - c(\lambda_1 - 1)\frac{(\lambda_1)^{\frac{\sigma j_x}{1-\sigma}}}{(\lambda_1)^{\frac{1}{1-\sigma}}}\right\}$$

$$B = \beta\left[(1-\mu)(1-\varepsilon) + \varepsilon\mu\right]\left(\lambda_2(i)\right)^{\frac{\sigma}{1-\sigma}\cdot j_z}$$

such that whenever the mandatory firing cost F is higher than $\bar{\bar{f}}(i)$, *innovators rank x projects higher than project z_i (i.e.,* $\Pi^f_{z_i}(F) < \pi(x)$*), and vice versa— whenever the mandatory firing cost F is lower than* $\bar{\bar{f}}(i)$, *innovators rank the z_i project higher than x projects (i.e.* $\pi(x) < \Pi^f_{z_i}(F)$*)*

Lemmas 1' and 2' imply that the qualitative properties of the threshold conditions in the basic model are preserved under the new assumptions of the model. Since Lemmas 1' and 2' guarantee that Lemma 3 and Lemma 4 in the previous section still hold, then the main result of the paper, namely, that employment protection legislation distorts the pattern of specialization in favor of medium-tech firms and thereby slows down the process of economic growth, carries through.

5. Empirical Motivation

The hypothesis that employment protection legislation affects productivity has recently received considerable attention in the empirical literature. The findings have confirmed that EPL *negatively* impinges on productivity and growth. However, while the literature presents several mechanisms through which EPL affects productivity it does not entirely rule out or exclusively adopt a specific mechanism. For example, Gust and Marquez (2004) find that burdensome labor market regulations in a number of European countries negatively affect firms' incentives to adopt new technologies and thereby slow down their productivity growth relative to the US. Ichino and Riphahn (2005), find a negative connection between employment protection and workers' efforts and attendance, namely, once employment protection is granted, the number of absence days per week (mainly for male workers) more than triples and productivity declines.[20] Bassanini, Nunziata and Venn (2008) find evidence of a negative impact of EPL on total factor productivity growth and claim that it reflects the effect of layoff restrictions on efficiency improvements.[21] In light of these divergent results, it would seem that there exists more than one single explanation to why firing costs negatively affect growth and productivity. In this paper we suggest that high mandatory firing costs place a burden on human-capital-intensive firms' screening process and therefore reduce innovation and growth. Although the data available on screening is sparse, we find data that can support our theoretical results that mandatory firing costs make screening in human-capital-intensive firms' more expensive and therefore reduce innovation and growth. A more rigorous empirical examination is left for future work.

Our model predicts that if the legal probation period during which employees can be dismissed without severance pay is sufficiently short then high firing costs would negatively affect specialization, innovation and growth. The rationale of this prediction is that under a short legal probation period, high-tech firms would not be able to complete a successful screening process without a costly adjustment of their labor force. In light of this prediction, we examine how legal probation periods in developed counties are correlated with technology-intensity.

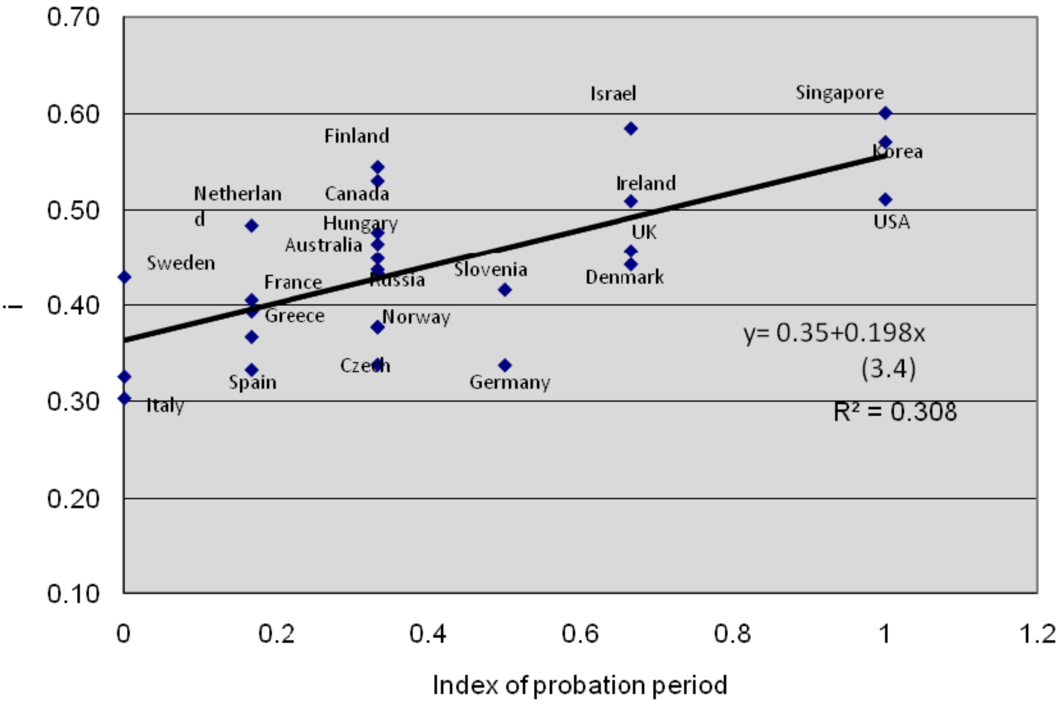
We first estimate, in simple indicative linear regressions, the correlation between the legal probation period in various countries and the share of high-tech patents in total patenting as well as the correlation between the probation period and the share of high-tech manufactured products and services in the gross value added. The data are for the year 2004 and encompasses most of the OECD countries as well as some other selected developing countries. [22] The regression results suggest that there are positive and significant correlations between the probation period and high-tech intensity. See the charts below.

[20] Female workers are on average more absent in all periods, the effect of the end of probation is estimated to be similar in absolute terms but smaller in relative terms.

[21]The impact of firing costs on employment and labor market flows has also been analyzed in several important studies. These studies show that a more strict employment protection reduces labor flows but has an ambiguous effect on the level of overall employment (see Lazear (1990), Bentolila and Bertola (1990), Bertola (1990) and Bentolila and Saint Paul (1992) .

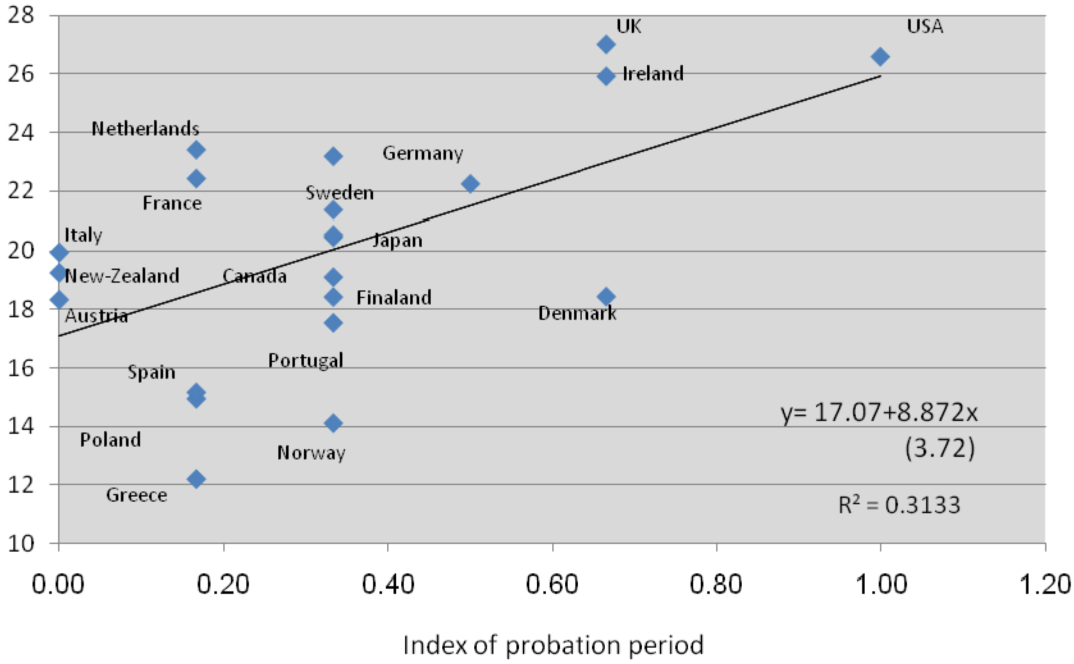
[22] The first regression includes: Australia ,Austria, Belgium ,Brazil, Canada, China, Czech, Denmark , Finland ,France,Germany, Greece, Hungary, India , Ireland, Israel , Italy, Japan, Korea ,Luxembourg, New Zealand , Netherlands, Norway ,Poland, Russian Federation ,Slovenia, South Africa, Singapore, Spain, Sweden, Turkey, United Kingdom, United States.
Due to missing data, the second regression does not include the following countries: Australia, Brazil, China, Czech Republic ,India, Israel, Korea, Luxembourg, Turkey, Slovenia, South Africa, Russian Federation,
The formula of the probation period index is given by 1-x where x is the trial period index as presented in the OECD Indicators on Employment Protection - annual time series data.

Figure 4: The share of High Tech patents in total patenting



Source: Data for the probation period was taken from the OECD Indicators on Employment Protection - annual time series data 1985-2008 OECD.
(see http://www.oecd.org/document/11/0,3343,en_2649_33927_42695243_1_1_1_1,00.html#data)
Data for high tech patents: OECD Patent Database and ANBERD(see www.oecd.org/sti/ipr-statistics) all data are for the year 2004. t statistics values are in parentheses.

Figure 5: The share of high tech in Value added (manufactures and Services)



Source: Data for the probation period was taken from the OECD Indicators on Employment Protection - annual time series data 1985-2008 OECD
(see http://www.oecd.org/document/11/0,3343,en_2649_33927_42695243_1_1_1_1,00.html#data)
Data for high tech value added was taken from STI scoreboard 2007
http://oberon.sourceoecd.org/vl=13595767/cl=27/nw=1/rpsv/sti2007/d-4.htm

Economies with relatively long legal probation periods such as the US (with unlimited legal probation period (index=1)), UK and Ireland (with 12 months and (index=0.67) are among the economies with the highest share in high-tech patenting (51% in the US and Ireland, and 46% in UK).[23] Furthermore, these economies have the highest share of high tech in manufactured products and services in total gross value added (27% in the US, and 26% in UK and Ireland). At the other extreme, there are OECD countries such as Italy, Spain and Norway with very short legal probation periods (1, 2.5 and 3 months, respectively) and low share in high tech patenting (30%, 33% and 38%, respectively). These countries also have a relatively low share of high-tech in total gross value added (20%, 14% and 15%, respectively).

Since our paper argues that mandatory firing costs impose a burden on a firm's screening process, it will be also useful to examine whether the presence of a screening devise indeed decreases the effect of firing costs on specialization. A widely recognized screening device are Fixed Terms Contracts under which employers can employ workers in temporary jobs and consequently dismiss them once the contractual duration of employment ends (see Boockmann and Hagen (2008)).

In an important paper, Botero et al. (2004) constructed a fixed-term contracts' index (FTCs) which measures how difficult it is for firms to legally employ workers in temporary jobs and for how long. If our hypothesis is indeed correct (i.e., that mandatory firing costs negatively impinge on firms' screening process), then widely used fixed term contracts *should decrease the impact of firing costs on firms specialization.*

We therefore test our hypothesis by estimating the effect of firing cost on the size of the High-technology exports while controlling with temporary employment. We use ordinary least squares (OLS) regression and then compute White "robust" standard errors.[24] The regression equation is given by:

$$HTEX_i = \alpha + \alpha_1 FC_i + \alpha_2 FTC_i + \varepsilon_i \tag{15}$$

where i is the country index, $HTEX$ is the share of High-technology exports as a percentage of total manufactured exports, FC is a variable that measures firing costs expressed in weekly wages, and FTC is Botero et al. (2004) index.

The original Botero et al. (2004) sample includes 85 countries, many of which are undeveloped. In order to examine only countries for which the innovators' dilemma of weather to embark on High-tech or Medium Tech applies, we excluded from Bortelo's sample all the countries that according to the World Bank classification are below the upper-middle income group.[25]

Table 1 contains the regression results. [26]

[23] STI scoreboard 2007 http://oberon.sourceoecd.org/vl=13595767/cl=27/nw=1/rpsv/sti2007/d-4.htm

[24] This estimates coefficient covariance in the presence of heteroskedasticity.

[25] See: http://data.worldbank.org/about/country-classifications.

[26] See appendix A-3 for more details on the data sets.

Table 1

Dependent Variable: High Tech Export			
Regressors	**EQ1**	**EQ2**	**EQ3**
Const	16.989* (6.56)	18.406* (5.963)	20.465* (5.75)
Fixed Term Contracts (FTC)		-10.766* (t=-2.234) (Pvalue=0.03)	--9.939* (t=-2.14) (P_{value}=0.0375)
Firing cost	-0.065* (t=-2.028) (P_{Value}=0.048)		-0.0506* (t=-1.806) (P_{Value}=0.078)
Adjusted R-squared	0.056	0.0755	0.096
F-statistic	4.11	4.99	3.36
No of Observation	45	45	45

** t statistics values are in parentheses.*

*** An asterisk indicates significant at $p \leq 0.1$.*

As expected, the FTC index is significant and has a negative sign in all regression results. Furthermore, as our theory predicts, the firing cost coefficient is significant with and without FTC, but decreases (in absolute value) and becomes less significant after introducing the FTC variable. This empirical result does indeed corroborate with our hypothesis, since the easier it is for employers to hire workers on fixed terms contracts (and thereby screening them), the less relevant are firing costs to specialization.

6. Summary

This paper focused on the burden that high firing costs place on the screening process of human-capital-intensive firms. It is shown that when firing costs are high and workers' productivity is ex ante unknown, innovators will embark on relatively less human-capital intensive projects since screening become expensive. Firing costs distort the pattern of specialization toward medium-tech industries rather than high-tech industries and thereby affect output and labor productivity growth negatively. These theoretical results are consistent with the US productivity revival in the 1990's as well as with the evolving of US-EU productivity gap.

From a policy perspective, our paper suggests that when governments implement employment protection policies they should also create sufficient conditions for high-tech firms to screen their workers. This can be done either by extending the length of the legal trial period or by easing the use of fixed-term contracts.

References

Aghion P., Howitt P. (1992), 'A Model of Growth through Creative Destruction', *Econometrica,* **60**, 323-51

Alesina A., Zeira J. (2006), 'Technology and Labor Regulations', *HIER Discussion Paper*, **2123**, Harvard Institute of Economic Research, Harvard University

Bassanini A., Nunziata L., Venn D. (2009), 'Job Protection Legislation and Productivity Prowth in OECD countries,' *Economic Policy*, **24**, 349-402

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(5)**, 1013-1047

Bertola G. (1992), 'Labor Turnover Costs and Average Labor Demand', *Journal of Labor Economics*, **10**, 389-411

Bertola G. (1994),' Flexibility, Investment, and Growth', *Journal of Monetary Economics*, **34**, 215-228

Boockmann B., Hagen T. (2008) 'Fixed-Term Contracts as Sorting Mechanisms: Evidence from Job Durations in West Germany', *Labor economics*, **15**, 984-1008

Botero J. *et al.* (2004), 'The Regulation of Labor', *Quarterly Journal of Economics*, **119**, 1339-1382

Comin D., Hobijn G. (2004), 'Cross-Country Technology Adoption: Making the Theories Face the Facts', *Journal of Monetary Economics*, **51**, 39-83

Davis S.J., Henrekson M. (1997) 'Industrial Policy, Employer Size and Economic Performance in Sweden', Freeman R. B., *The Welfare State in Transition: Reforming the Swedish Model*, University of Chicago Press.

Gordon R., J. (2000) 'Does the "New Economy" Measure Up to the Great Inventions of the Past?,' *Journal of Economic Perspectives*, **14**, 49-74

Grossman G.M., Helpman E. (1991), 'Quality Ladders in the Theory of Growth', *The Review of Economic Studies*, **58**, 43-61

Grossman G.M., Helpman E. (1991), 'Quality Ladders and Product Cycles,' *The Quarterly Journal of Economics*, **106**, 557-86

Gust C., Marquez J. (2004), 'International Comparisons of Productivity Growth: the Role of Information Technology and Regulatory Practices', *Labour Economics*, **11**, 33-58

Hopenhayn H., Rogerson R, (1993), 'Job Turnover and Policy Evaluation: A General Equilibrium Analysis', *Journal of Political Economy*, **101**, 915-938

Ichino A., Riphahn R. (2005), 'The Effect of Employment Protection on Worker Effort: Absenteeism During and After Probation,' *Journal of the European Economic Association*, **3(1)**, 120-143

Jorgenson D. W., Stiroh K.J. (2000). 'U.S. Economic Growth at the Industry Level', *American Economic Review*, **90**, 161-167

Jorgenson D. W., Mun S. Ho., Stiroh K.J. (2008), 'A Retrospective Look at the U.S. Productivity Growth Resurgence', *Journal of Economic Perspectives*, **22**, 3-24

Lazear E. (1990), 'Job Security Provisions and Employment', *Quarterly Journal of Economics*, **105(3)** 699-726

OECD. (2003), *ICT and Economic Growth- Evidence from OECD Countries Industries and Firms*, OECD Publishing

Saint-Paul G. (1997) 'Is Labour Rigidity Harming Europe's Competitiveness? The effect of Job Protection on the Pattern of Trade and Welfare', *European Economic Review*, **41**, 499-506

Saint-Paul G. (2002) 'Employment Protection, International Specialization, and Innovation', *European Economic Review*, **46**, 375-395.

Van Ark B., O'Mahony M, and Timmer M. (2008) 'The Productivity Gap between Europe and the U.S.: Trends and Causes', *Journal of Economic Perspectives*, , **22**, 25-44.

Zeira J. (1998), 'Workers, Machines, and Economic Growth', *The Quarterly Journal of Economics*, **113**, 1091-1117

Appendix

A-1 Mathematical Proofs

Proof of Proposition 2: Let $\widetilde{Z}$ denote the set of all products i of type z that innovators in economy B did not produce due to high firing costs (i.e., $\widetilde{Z} = [0,1] \setminus Z(F_B)$). Note that $j_{z_i} = 0$ for all products in $\widetilde{Z}$. Suppose now that at some period T>0 where

$$T > \frac{1}{\frac{\sigma}{1-\sigma}\log(\lambda_1)} \log\left(\frac{\left[(\lambda_2(0)-1)-(\beta(\frac{1-\mu}{\mu}))\right][\lambda_1/\lambda_2(0)]^{\frac{1}{1-\sigma}}}{(\lambda_1 - 1)} \right),$$

firing cost F_B in economy B is reduced to zero.

Since *the quality rank of all other intermediate goods that are produced is equal to j=T (and thereby j_x=T for all products is $X_t(F_B)$), then the threshold value*

$$\bar{\bar{f}}(i) = \min\left\{ \frac{(\lambda_2(i)-1)}{\beta(\frac{1-\mu}{\mu}))} - \frac{(\lambda_1 - 1)[\lambda_2(i)]^{(\frac{1}{1-\sigma})} \cdot (\lambda_1)^{[(\frac{\sigma}{1-\sigma}) j_x]}}{[\lambda_1]^{(\frac{1}{1-\sigma})} (\lambda_2(i))^{[(\frac{\sigma}{1-\sigma}) \cdot j_z]} \cdot \beta(\frac{1-\mu}{\mu}))} - 1 \, , \, \frac{1-\beta}{\beta} \right\}$$

becomes less than zero for all products in $\widetilde{Z}$.

Thus, even if firing cost F_B has declined to zero, innovators will not find it optimal to shift their activities from x projects to z projects since the z-projects in $\widetilde{Z}$ are less profitable than the x-projects that were already developed and produced.

Proof of Proposition 3: Let $w_j = g(\hat{m}, \hat{h}, j)$ and $Y_t = f(\hat{m}, \hat{h}, j)$ denote real wage and aggregate output, respectively, as given in equations (8) and (9). It is easy to verify that:

(*i*) $\frac{d}{dt} g(\hat{m} - t, \hat{h} + t, j) > 0$, (*ii*) $\frac{d}{dt} f(\hat{m}-t, \hat{h}+t, j) > 0$,

(*iii*) $\frac{d}{dt}\left[\frac{g(\hat{m}-t, \hat{h}+t, j+1)}{g(\hat{m}-t, \hat{h}+t, j)}\right] > 0$,

(*iv*) $\frac{d}{dt}\left[\frac{f(\hat{m}-t, \hat{h}+t, j+1)}{f(\hat{m}-t, \hat{h}+t, j)}\right] > 0$.

A-2 Labor Market Equilibrium and Determination of Final Good Output

Market clearing conditions in the labor market include:

$$\begin{cases} \bar{L} = \hat{m} \cdot x^* + \frac{\hat{h}}{\mu} \cdot z^* & \text{during the } [0,\beta) \text{ testing period} \\ \bar{L} = \hat{m} \cdot x^* + \hat{h} \cdot z^* & \text{during } [\beta,1] \end{cases} \tag{*}$$

Substituting equation (5) into equation (*) yields:

$$\begin{cases} \bar{L} = \hat{m}\frac{(Y)(\lambda_1)^{\frac{\sigma}{1-\sigma}j}}{[\lambda_1 w]^{\frac{1}{1-\sigma}}} + \frac{\hat{h}}{\mu}\frac{(Y)(\lambda_2)^{\frac{\sigma}{1-\sigma}\cdot j}}{[\lambda_2 w]^{\frac{1}{1-\sigma}}} & \text{during the } [0,\beta) \text{ testing period} \\ \bar{L} = \hat{m}\frac{(Y)(\lambda_1)^{\frac{\sigma}{1-\sigma}j}}{[\lambda_1 w]^{\frac{1}{1-\sigma}}} + \hat{h}\frac{(Y)(\lambda_2)^{\frac{\sigma}{1-\sigma}\cdot j}}{[\lambda_2 w]^{\frac{1}{1-\sigma}}} & \text{during } [\beta,1] \end{cases} \tag{**}$$

and therefore

$$\begin{cases} w=\left(\dfrac{Y}{\overline{L}}\right)^{1-\sigma}\left\{\hat{m}\dfrac{(\lambda_1)^{\frac{\sigma}{1-\sigma}j}}{[\lambda_1]^{\frac{1}{1-\sigma}}}+\dfrac{\hat{h}}{\mu}\dfrac{(\lambda_2)^{\frac{\sigma}{1-\sigma}\cdot j}}{[\lambda_2]^{\frac{1}{1-\sigma}}}\right\}^{1-\sigma} & \text{during the } [0,\beta) \text{ testing period} \\ w=\left(\dfrac{Y}{\overline{L}}\right)^{1-\sigma}\left\{\hat{m}\dfrac{(\lambda_1)^{\frac{\sigma}{1-\sigma}j}}{[\lambda_1]^{\frac{1}{1-\sigma}}}+\hat{h}\dfrac{(\lambda_2)^{\frac{\sigma}{1-\sigma}\cdot j}}{[\lambda_2]^{\frac{1}{1-\sigma}}}\right\}^{1-\sigma} & \text{during } [\beta,1] \end{cases} \qquad (***)$$

By substituting the last equation into equation (5) and then into equation (1) we get that at trial period [0,β)

$$Y=\frac{\left[\hat{m}\left((\lambda_1)^j\dfrac{(\lambda_1)^{\frac{\sigma}{1-\sigma}j}}{\lambda_1^{\frac{1}{1-\sigma}}}\right)^{\sigma}+\hat{h}\left((\lambda_2)^j\dfrac{(\lambda_2)^{\frac{\sigma}{1-\sigma}\cdot j}}{\lambda_2^{\frac{1}{1-\sigma}}}\right)^{\sigma}\right]^{\frac{1}{\sigma}}}{\left\{\hat{m}\dfrac{(\lambda_1)^{\frac{\sigma}{1-\sigma}j}}{[\lambda_1]^{\frac{1}{1-\sigma}}}+(\hat{h}/\mu)\dfrac{(\lambda_2)^{\frac{\sigma}{1-\sigma}\cdot j}}{[\lambda_2]^{\frac{1}{1-\sigma}}}\right\}}\cdot\overline{L}$$

and at sub-period [β,1]

$$Y=\frac{\left[\hat{m}\left((\lambda_1)^j\dfrac{(\lambda_1)^{\frac{\sigma}{1-\sigma}j}}{\lambda_1^{\frac{1}{1-\sigma}}}\right)^{\sigma}+\hat{h}\left((\lambda_2)^j\dfrac{(\lambda_2)^{\frac{\sigma}{1-\sigma}\cdot j}}{\lambda_2^{\frac{1}{1-\sigma}}}\right)^{\sigma}\right]^{\frac{1}{\sigma}}}{\left\{\hat{m}\cdot\dfrac{(\lambda_1)^{\frac{\sigma}{1-\sigma}j}}{[\lambda_1]^{\frac{1}{1-\sigma}}}+\hat{h}\cdot\dfrac{(\lambda_2)^{\frac{\sigma}{1-\sigma}\cdot j}}{[\lambda_2]^{\frac{1}{1-\sigma}}}\right\}}\cdot\overline{L}$$

By substituting the last equation into the wage equation (***) we get the wage rate equilibrium:

$$w=\left[\hat{m}\left((\lambda_1)^j\frac{(\lambda_1)^{\frac{\sigma}{1-\sigma}j}}{\lambda_1^{\frac{1}{1-\sigma}}}\right)^{\sigma}+\hat{h}\left((\lambda_2)^j\frac{(\lambda_2)^{\frac{\sigma}{1-\sigma}\cdot j}}{\lambda_2^{\frac{1}{1-\sigma}}}\right)^{\sigma}\right]^{\frac{1-\sigma}{\sigma}}.$$

A-3 Statistical Data

The regression in equation (15) includes three variables:

HTEX- High-technology exports are products with high R&D intensity.

Examples for such products are aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery. Series code in the World Bank data catalogue: TX.VAL.TECH.MF.ZS.

FTC- We used Botero et al (2004) data and definition. The term 'fixed-term contract' refers to workers employed for fixed periods of weeks, months, or years. In many countries a person working for two or three days per week is considered a fixed-term, rather than a part-time, worker. The FTC synthetic index constructed by Botero et al (2004) measures the difficulties in employment through temporary contracts. Specifically, the index gets values from 0 to 1. Higher values are associated with Greater difficulties in temporary employment of workers.[27]

Firing cost - the cost of advanced notice requirements, severance payments and penalties due when terminating a redundant worker, expressed in weekly wages. Series code in World Bank data catalogue: IC.EMP.FIRE.WK.

[27] This data set can be found in : http://www.economics.harvard.edu/faculty/shleifer/dataset