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Egbert L.W. Jongen and Sabine S. Visser

CPB Netherlands Bureau for Economic Policy Analysis
Van Stolkweg 14
P.O. Box 80510
2508 GM The Hague, the Netherlands

Telephone	+31 70 338 33 80
Telefax	+31 70 338 33 50
Internet	www.cpb.nl

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Abstract in English

The impact of employment protection on employment and productivity seems ambiguous in empirical work. We seek to explain why, studying various types of employment protection in a vintage model with specific investments by firms and workers. First, the analysis shows that the impact of severance pay can be quite different from other types of employment protection. Lumping them together, as in the OECD indicator, then seems a poor empirical strategy, and we provide empirical support for this. Second, starting from underinvestment in specific investments, firing costs may actually raise productivity, despite the sclerosis effect on the production structure. Third, we show that the tenure profile of employment protection matters. The impact of constant employment protection, popular in theoretical work, is quite different from the impact of rising employment protection, popular in practice. We illustrate a number of points quantitatively in a calibration exercise for the Netherlands.

Key words: employment protection, employment, productivity, specific investments

Abstract in Dutch

Empirisch onderzoek geeft geen eenduidig effect van ontslagbescherming op de werkgelegenheid en de productiviteit. In dit paper onderzoeken we hoe dat kan. Daartoe bestuderen we verschillende vormen van ontslagbescherming in een jaargangenmodel met specifieke investeringen door werknemers en werkgevers. Ten eerste laat de analyse zien dat het effect van ontslagvergoedingen anders is dan andere vormen van ontslagbescherming. Het samenpakken van verschillende vormen van ontslagbescherming voor empirisch onderzoek, zoals in de indicator van de OESO, is daarom onwenselijk. Een eigen empirische analyse ondersteunt deze stelling. Ten tweede, hogere ontslagkosten kunnen inderdaad leiden tot een hogere productiviteit, mits er initieel sprake is van een onderinvestering in specifieke investeringen. Ten derde, het verloop van de ontslagbescherming met de duur van de baan is belangrijk. Het effect van constante ontslagbescherming, populair in theoretisch onderzoek, is wezenlijk anders dan van oplopende ontslagbescherming, populair in de praktijk. We illustreren verschillende punten kwantitatief in een gekalibreerde versie van het model voor Nederland.

Steekwoorden: ontslagbescherming, werkgelegenheid, productiviteit, specifieke investeringen

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1 Introduction

Employment protection legislation (EPL) remains a hotly debated topic, both in academia and in the political arena.[1] Indeed, where the negative effect of EPL on labour market dynamics is well established, there is no such certainty about the effect of EPL on employment and productivity, here `ambiguity´ seems to be the robust finding.[2] In light of this ambiguity, it is not surprising that there is much discussion amongst researchers and policymakers regarding the impact of EPL, in which priors often seem to dominate the evidence (Freeman, 2005). Another result of the ambiguity is that some researchers conclude that time spent worrying about employment protection is probably time largely wasted (Nickell and Layard, 1999). Although we are not the worrying type, we agree with Addison and Teixeira (2001) that studying the impact of EPL is not just divertissement. Indeed, inconclusiveness should not lead to indifference (Young, 2003). In this paper, we therefore further explore where the ambiguity might be coming from. Specifically, we show that part of the ambiguity may be the result of lumping together different types of EPL that differ in their impact, and give some empirical support for this. For the different types of EPL we also show that the ambiguity can be real with respect to employment and productivity, when the returns to specific investments are not protected by a contract but bargained over ex post. We further show that the tenure profile of EPL matters. Indeed, the impact of constant EPL, popular in theoretical work, can be quite different from rising EPL, popular in practice. We also consider the role of labour supply in the overall effect of EPL, which empirical studies suggest might be a quantitatively important variable to consider in the case of EPL. Next to employment and output, we further consider the effect on welfare. EPL is often judged on its impact on GDP, but this can be an imperfect indicator for welfare (even in the absence of insurance gains). We illustrate these points in a calibration exercise for the Netherlands.

A large number of empirical studies find that stricter EPL is associated with slightly lower employment and labour supply, and slightly higher unemployment. However, more important seems the variation in the findings relative to the mean, the average effect across studies is not significantly different from zero. Studies into the effect of EPL on productivity are more scarce, but again the results seem mixed. Using cross-country data, Nickell and Layard (1999) find that EPL is either not related to productivity or is positively related to productivity, depending on the specification. Scarpetta *et al.* (2002) find a negative effect of EPL on productivity growth, but

[1] Correspondence to: Egbert L.W. Jongen, CPB Netherlands Bureau for Economic Policy Analysis, P.O. Box 80510, 2508 GM The Hague, the Netherlands, e-mail: jongen@cpb.nl. We thank Jan Boone, Peter Broer, Wolter Hassink, Ruud de Mooij and participants of the COST A23 meeting in Essen, the workshop on "The Economics of Dismissal Law and Employment Protection" at the Utrecht School of Economics, and seminar participants at CPB Netherlands Bureau for Economic Policy Analysis and Netspar for comments and suggestions. Furthermore, we thank Debby Lanser for the `trick´ of converting a differential equation with an endpoint condition into a differential equation with an initial condition, and Evangelia Bourmpoula for running the regressions in Section 3. All remaining errors are our own.

[2] See Deelen *et al.* (2006), they review the theoretical and empirical literature on EPL, and try to distill some fruitful reform options from this literature for the Dutch case.

only for countries with an intermediate degree of centralisation/coordination in wage bargaining (as in the Netherlands). Using panel data for 60 countries by sector, Caballero *et al.* (2004) find that EPL has a strong negative effect on productivity in countries with strong rule of law, while the effect is negligible in countries with weak rule of law. Autor *et al.* (2007) find (tentative) evidence that EPL reduces productivity. Belot *et al.* (2007) find an inverted U-shape for the relation between EPL and GDP per capita, with low levels of EPL raising GDP per capita and high levels of EPL reducing GDP per capita. The question then is whether the ambiguity is perhaps more apparent than real. Indeed, authors typically run cross-country panel regressions with limited variation in EPL over time, and the quantification of EPL is rather subjective (OECD, 2004). So, if we just had better data, perhaps we could find the `real´ effect of EPL? Below we show that part of the ambiguity indeed may be the result of a poor empirical strategy. However, we also show that the effect on employment and productivity may indeed go either way.

This paper is partly inspired by the contribution of Ljunqvist (2002). To understand the apparent ambiguity in the relation between layoff costs (actually layoff taxes) and employment in earlier *theoretical* work he simulates variations in layoff costs in three different model environments: a search model, a matching model and a model with employment lotteries. By tracing the results back to the underlying assumptions, one can understand why in *e.g.* Hopenhayn and Rogerson (1993) and Saint-Paul (1995) employment falls when layoff costs rise, whereas the reverse is true in Alvarez and Veracierto (1998) and Mortensen and Pissarides (1999). In particular, layoff costs are more likely to reduce employment when they can push up wages and/or discourage labour participation. Where Ljunqvist (2002) focused on different model environments, we focus on differences resulting from different types of EPL and the tenure profile of EPL. How does the impact of severance pay differ from the impact of firing costs? How does the impact of firing taxes differ from the impact of firing costs? And what difference does it make when we assume rising rather than flat EPL?

Next to the impact on employment, we also study the impact on productivity and consumption, where the effect on consumption can again be different from the effect on output due to *e.g.* investment costs. To allow for a potential ambiguous effect on productivity, we have both potential `sclerosis´ from reduced turnover in the economy due to EPL and specific investments[3] combined with ex post bargaining.

The model integrates the vintage model of Caballero and Hammour (1998a) with the Mortensen and Pissarides model with specific investments by Belot *et al.* (2007). To the analysis of Caballero and Hammour (1998a), we add the analysis of severance pay and firing taxes, and the relevance of the tenure profile of EPL. We show that also in this setup, severance pay is

[3] Apart from the search costs and the commitment to pay firing costs and/or taxes, which are also specific investments. To this we add specific investments that increase the productivity of a match.

neutral when it is zero for new matches. In general equilibrium, wages fall to leave job creation unaffected, as in Mortensen and Pissarides (1999) and in the case with flexible wages in Garibaldi and Violante (2005). We further consider the relevance of rising EPL rather than the flat EPL assumed in Caballero and Hammour (1998a). Furthermore, we consider the productive role of firing taxes in preventing excessive firings in the presence of unemployment insurance, following the lead of Blanchard and Tirole (2008). We further show results similar to Belot *et al.* (2007) for the case of specific investments in productivity and ex post bargaining, but then in a vintage setup. Furthermore, we present a calibration exercise for the Netherlands in order to illustrate the various points quantitatively and to gauge their empirical relevance.

The outline of the paper is as follows. In Section 2, we outline the model we use to study the impact of the different types of EPL. In Section 3, we present a qualitative study of the balanced growth path. We consider the differential impact of severance pay and firing costs and taxes, the relevance of the tenure profile of EPL, and compare the first best solution with the market outcome and the second best role EPL may play in our setup. In Section 4, we calibrate the model to the Dutch labour market and simulate the impact of EPL under different assumptions. Section 5 discusses some limitations of the analysis and how these might affect the results. Section 6 concludes.

2 The model

2.1 Informal overview

Before we turn to the formal expressions, we first give an informal overview of the model. Workers flow between the states of employment and unemployment.[4] A matching function determines the flow into employment, with unemployed workers and vacancies as inputs. The flow from employment into unemployment consists of an exogenous and an endogenous part. The exogenous flow captures separations to which no EPL applies (because *e.g.* the worker leaves or because the firm goes bankrupt due to a sudden shock). Endogenous separations result from the scrapping of old vintages of production.[5] Once a match is created, the productivity is fixed for the duration of the match. However, the productivity of new matches keeps growing. Hence, at some point the productivity of the match is no longer sufficient to generate a surplus, and the worker and the firm separate.

Employment protection affects both the creation and destruction of matches. EPL may deter match creation by increasing labour costs and may deter match destruction by making separation more costly. As EPL can decrease both creation and destruction, the impact on the stock of employment (and unemployment) is potentially ambiguous.

EPL affects productivity through its effect on match durations. When EPL increases match durations there are two opposing effects on productivity. On the one hand, longer match durations imply that more workers will be working in older vintages, reducing average productivity. On the other hand, longer match durations also make it more profitable to invest in the match. Higher specific investments may overturn the `sclerosis´ effect of EPL on productivity.

Wages are determined by continuous time Nash bargaining, which splits the remaining surplus of a match between the worker and the firm. Because we assume that the returns from specific investments cannot be protected by a contract, Nash bargaining implies that we have a hold up problem for specific investments on both the firm and worker side. In this setting, EPL can improve welfare by reducing the underinvestment problem.

Finally, the government sets the level and tenure profile of the different types of EPL, the level of unemployment insurance benefits, and balances the budget via unemployment insurance premiums. The presence of unemployment insurance benefits provides another rationale for EPL in the model, next to underinvestment in specific investments.

[4] In the base setup, labour supply is fixed. In Section 5, we consider an extension where labour supply (in persons) is endogenous.

[5] Hence, we do not allow firms and workers to relabel a layoff a quit so as to avoid layoff costs or taxes. Since workers lose their entitlement to UI when they quit their job in the Netherlands, this may not be so problematic. For an analysis of the impact of EPL on quits, see Blanchard and Portugal (2001), and for an analysis of the impact of EPL on job-to-job mobility see Pries and Rogerson (2005).

Below we consider the setup in more detail. We start with the value functions for firms and workers, and the resulting surplus of a match. We then consider the sharing of this surplus, and the determination of specific investments by firms and workers. Finally, we consider the flow equilibrium over the states of employment and unemployment, and the budget constraint for the government.

2.2 Value functions

2.2.1 Firms

Let t denote time, and τ denote a specific vintage created at time $t = \tau$. Furthermore, let r denote the discount rate of firms and let $q(\theta)$ denote the rate at which a vacancy is converted into a productive match. The rate at which vacancies are converted into matches depends on θ, the ratio of vacancies to unemployed workers (or `labour market tightness´). We will only consider steady states, and suppress a time subscript when possible, for example for $\theta(t)$. $A(t)$ is the leading technology at time t and grows exponentially at rate γ, $A(t) = A(0)e^{\gamma t}$. The cost of holding a vacancy is $vA(t)$ in period t. The firm further sinks another specific investment $i_f A(t)$ into the match so as to raise its productivity, *e.g.* through firm specific training.

The value of posting a vacancy at t, $V(t)$, is implicitly given by the following asset equation

$$rV(t) = -vA(t) + q(\theta)(\max_{i_f}\{J(i_f, i_w, t, t) - i_f A(t)\} - V(t)) + \frac{\partial V(t)}{\partial t}, \tag{2.1}$$

where $J(i_f, i_w, t, t)$ denotes the value of a newly created match given the specific investments by the firm and the worker ($i_w A(t)$, see below). The symbol t appears twice, once for the vintage and once for time, which coincide at the time of creation. The return on a vacancy is the sum of (minus) the per period vacancy cost, the rate at which a vacancy is converted into a productive job times the associated `capital gain´, and the change in the value of a vacancy with time.

Denote the value of a filled position created at τ at some future date $t > \tau$ for the firm by $J(i_f, i_w, \tau, t)$. At the moment of creation the productivity of the match is fixed. Furthermore, for simplicity we assume that workers and firms can only make specific investments at the moment of creation. The productivity of a match created at τ is given by $(c_0 + c_f {i_f}^{\rho_f} + c_w {i_w}^{\rho_w})A(\tau)$, where c_0 is the part of output which is not due to specific investments, $c_f {i_f}^{\rho_f}$ is the part due to specific investments by the firm and $c_w {i_w}^{\rho_w}$ is the part due to specific investments by the worker. Denote wages for an individual worker in a match created at τ at time t with specific investments i_f and i_w by $w(i_f, i_w, \tau, t)A(t)$, and let $pA(t)$ denote a premium levied on employers to finance unemployment insurance benefits. Finally, let δ denote the exogenous separation rate. The value of a match from vintage τ at time t, $J(i_f, i_w, \tau, t)$, is implicitly given by

$$\begin{aligned} rJ(i_f, i_w, \tau, t) = {} & (c_0 + c_f {i_f}^{\rho_f} + c_w {i_w}^{\rho_w})A(\tau) - w(i_f, i_w, \tau, t)A(t) \\ & - pA(t) + \delta(V(t) - J(i_f, i_w, \tau, t)) + \frac{\partial J(i_f, i_w, \tau, t)}{\partial t}. \end{aligned} \tag{2.2}$$

The return on a filled position is the sum of the difference between the productivity of the match and the wages and premiums the firm has to pay, a capital loss term when an exogenous separation occurs, and the change in the value of the match with time.

Matches will continue production up to the point where it no longer pays to stay together, when the discounted value of the match becomes lower than the outside option. The outside option for the firm is to pay the EPL and post a vacancy. The firm may face three types of EPL when a job is endogenously terminated: i) severance pay f_{sp}, ii) a firing cost f_c, and iii) a firing tax f_t. For an individual match the latter two are the same, but in general equilibrium the effects may differ (see below). We assume that EPL is indexed by the leading technology $A(t)$. Furthermore, EPL may rise with tenure, where α_0 reflects the part at creation (which may be zero), and for every period of tenure it increases by α_1. For notational convenience we assume that the tenure profiles of all types of EPL are the same. The date at which a unit created at t is endogenously destroyed is $t+T(t)$, where $T(t)$ is the duration of a match conditional on survival until $t+T(t)$. The EPL the firm has to pay when a job is destroyed at $t+T(t)$ is given by $(\alpha_0+\alpha_1 T(t))(f_{sp}+f_c+f_t)A(t+T(t))$. So, the terminal condition for firms for a match created at τ is

$$J(i_f,i_w,\tau,\tau+T(\tau)) = V(\tau+T(\tau)) - (\alpha_0+\alpha_1 T(\tau))(f_{sp}+f_c+f_t)A(\tau+T(\tau)). \tag{2.3}$$

Along the balanced growth path the value of a vacancy will be zero (see below), hence at termination the discounted value of a firm excluding the EPL obligations will be negative. Firms terminate when the discounted value of the losses exceeds the expenditures on EPL.

2.2.2 Workers

For workers we assume that the subjective discount rate is also r. $i_w A(t)$ is the specific investment the worker sinks into the relation. The counterpart of the asset equation for vacancies is the asset equation for the state of unemployment. Unemployed individuals receive unemployment insurance benefits $b_{ui}A(t)$ and potentially a lump sum transfer $y_{ls}A(t)$. Furthermore, we also introduce an (ad hoc) instantaneous utility term $b_{ld}A(t)$ in unemployment which may reflect the difference in leisure time in employment and unemployment and/or a disutility in unemployment due to *e.g.* the loss of a social network. The variable $b_{ld}A(t)$ gives us some additional freedom in the calibration later on. Finally, $\theta q(\theta)$ is the job finding rate for an unemployed worker. The value of unemployment at time t, $U(t)$, then follows from

$$\begin{aligned} rU(t) &= (b_{ui}+y_{ls}+b_{ld})A(t) + \theta q(\theta)(\max_{i_w}\{E(i_f,i_w,t,t) - i_w A(t)\} - U(t)) \\ &\qquad + \frac{\partial U(t)}{\partial t} \\ &= \widetilde{w}A(t) + y_{ls}A(t) + \frac{\partial U(t)}{\partial t}. \end{aligned} \tag{2.4}$$

once we introduce $\widetilde{w}A(t) \equiv (b_{ui}+b_{ld})A(t) + \theta q(\theta)(\max_{i_w}\{E(i_f,i_w,t,t) - i_w A(t)\} - U(t))$ as the (private) `shadow value´ of labour (excluding the lump sum transfer, for notational convenience). The return in unemployment is the sum of the instantaneous income and the utility component (b_{ld}), the rate at which unemployed individuals find a job times the associated gain, and the change in the value of unemployment with time. Note that instantaneous utility is linear in income. Hence, the marginal utility of income is constant, so there will be no insurance gains from EPL in this setup.

The asset equation for holding a job created at τ at some date $t > \tau$, $E(i_f, i_w, \tau, t)$, is

$$\begin{aligned} rE(i_f,i_w,\tau,t) = (w(i_f,i_w,\tau,t)+y_{ls})A(t)+\delta(U(t)-E(i_f,i_w,\tau,t)) \\ +\frac{\partial E(i_f,i_w,\tau,t)}{\partial t}. \end{aligned} \tag{2.5}$$

Hence, the return on holding a job of vintage τ at t is the sum of the instantaneous wage for that vintage at time t and the lump sum transfer, the drop in discounted lifetime utility when the worker becomes unemployed (a `capital loss´), and the change in the value with time.

The relation for $E(i_f, i_w, \tau, t)$ above holds from the creation date τ until the terminal date $\tau + T(\tau)$. Also for workers we have a terminal condition, the point in time when the value of continuing the match for the employee reaches the outside option. At the terminal date we have

$$E(i_f,i_w,\tau,\tau+T(\tau)) = U(\tau+T(\tau))+(\alpha_0+\alpha_1 T(\tau+T(\tau)))f_{sp}A(\tau+T(\tau)). \tag{2.6}$$

The outside option is the value of unemployment at the terminal date plus severance payments. Below we will see that the optimal terminal date will be the same for the firm and the employee.

2.2.3 Surplus

We can use the value functions of firms and workers to derive an expression for the surplus of a vintage from its creation till its end. The surplus of a match of vintage τ at time t, $S(i_f, i_w, \tau, t)$, is defined as the sum of the value of the match for the firm and the worker minus their outside options

$$\begin{aligned} S(i_f,i_w,\tau,t) = J(i_f,i_w,\tau,t)-(V(t)-(\alpha_0+\alpha_1(t-\tau))(f_{sp}+f_c+f_t)A(t)) \\ +E(i_f,i_w,\tau,t)-(U(t)+(\alpha_0+\alpha_1(t-\tau))f_{sp}A(t)). \end{aligned} \tag{2.7}$$

Before we proceed, we make two simplifying steps. First, note that the severance pay cancels. Indeed, the severance pay is a transfer from one party of the match to the other; hence, it can not be part of the surplus. Second, in the analysis below we only consider balanced growth paths where job creation is positive. Combined with an assumption of free entry of vacancies, this implies that the value of posting an additional vacancy will be zero along the balanced growth path (and also $\frac{\partial V(t)}{\partial t} = 0 \forall t$). Using these simplifications, and bringing the firing costs and taxes to the left, we get

$$S(i_f,i_w,\tau,t)+(\alpha_0+\alpha_1(t-\tau))A(t)(f_c+f_t)) = J(i_f,i_w,\tau,t)+E(i_f,i_w,\tau,t)-U(t). \tag{2.8}$$

Rename the left hand side $X(i_f, i_w, \tau, t)$. When we multiply both sides with $r + \delta$, and fill in the expressions for $J(i_f, i_w, \tau, t)$, $E(i_f, i_w, \tau, t)$ and $U(t)$, we obtain[6]

$$\begin{aligned}(r+\delta)X(i_f, i_w, \tau, t) = {} & (c_0 + c_f {i_f}^{\rho_f} + c_w {i_w}^{\rho_w})A(\tau) - (\widetilde{w} + p)A(t) \\ & + \frac{\partial X(i_f, i_w, \tau, t)}{\partial t}.\end{aligned} \tag{2.9}$$

This is a differential equation for the path of $X(i_f, i_w, \tau, t)$, which we can solve for the terminal conditions. Combining the terminal conditions for the employer and the employee, we find that the surplus at the terminal date is zero, $S(i_f, i_w, \tau, \tau + T(\tau)) = 0$. Solving the differential equation for this terminal condition, we obtain (see appendix A.1)

$$\begin{aligned}S(i_f, i_w, \tau, t) = {} & \int_t^{\tau+T(\tau)} ((c_0 + c_f {i_f}^{\rho_f} + c_w {i_w}^{\rho_w})A(\tau) \\ & -(\widetilde{w} + p)A(s))e^{-(r+\delta)(s-t)} ds \\ & +(\alpha_0 + \alpha_1(t-\tau))(f_c + f_t)A(t) \\ & -(\alpha_0 + \alpha_1 T(\tau))(f_c + f_t)A(\tau + T(\tau))e^{-(r+\delta)(\tau+T(\tau)-t)}.\end{aligned} \tag{2.10}$$

The remaining surplus of a vintage τ at some future date t is the discounted sum of the difference between productivity and the (private shadow) value of unemployment plus unemployment insurance premiums, plus the difference between firing costs and firing taxes at t and at the terminal date, discounted to time t.

2.3 Surplus sharing and specific investments

The surplus is split assuming continuous time Nash bargaining. Workers get their outside option and a share β of the remaining surplus, firms get their outside option and a share $(1-\beta)$ of the remaining surplus

$$E(i_f, i_w, \tau, t) = U(t) + (\alpha_0 + \alpha_1(t-\tau))f_{sp}A(t) + \beta S(i_f, i_w, \tau, t), \tag{2.11}$$

and

$$J(i_f, i_w, \tau, t) = -(\alpha_0 + \alpha_1(t-\tau))(f_{sp} + f_c + f_t)A(t) + (1-\beta)S(i_f, i_w, \tau, t), \tag{2.12}$$

respectively.

Given this sharing rule, we can determine the choice of specific investments by firms and workers. For simplicity, we assume that specific investments are made only at the point of

[6] Noting that $\frac{\partial J(i_f, i_w, \tau, t)}{\partial t} + \frac{\partial E(i_f, i_w, \tau, t)}{\partial t} - \frac{\partial U}{\partial t} = \frac{\partial X(i_f, i_w, \tau, t)}{\partial t}$.

creation of the match. The profit maximizing specific investments by the firm $i_f A(t)$ are given by

$$\begin{aligned}
i_f &= \arg\max_{i_f}\{J(i_f, i_w, t, t)\} - i_f A(t)\} \\
&= \arg\max_{i_f}\{-(\alpha_0 + \alpha_1(t-\tau))(f_{sp} + f_c + f_t)A(t) \\
&\quad +(1-\beta)S(i_f, i_w, \tau, t) - i_f A(t)\} \\
&= \left(c_f \rho_f \frac{1-\beta}{r+\delta}\left(1 - e^{-(r+\delta)T(t)}\right)\right)^{\frac{1}{1-\rho_f}}, \qquad (2.13)
\end{aligned}$$

and for workers utility maximising specific investments $i_w A(t)$ are given by

$$\begin{aligned}
i_w &= \arg\max_{i_w}\{E(i_f, i_w, t, t)\} - i_w A(t)\} \\
&= \arg\max_{i_w}\{U(t) + \alpha_0 f_{sp} A(t) + \beta S(i_f, i_w, t, t) - i_w A(t)\} \\
&= \left(c_w \rho_w \frac{\beta}{r+\delta}\left(1 - e^{-(r+\delta)T(t)}\right)\right)^{\frac{1}{1-\rho_w}}. \qquad (2.14)
\end{aligned}$$

We see that specific investments depend positively on the expected match duration $T(t)$, which is how EPL will affect them. We also see that specific investments do not depend on EPL variables directly. Indeed, EPL does not overcome the contracting problem for specific investments. Workers get only a share β of the returns of their specific investments, and firms only get a share $1-\beta$ of their specific investments. Hence, the social returns are higher than the private returns. Any policy that shifts match durations $T(t)$ up therefore has the indirect benefit of raising specific investments (more on this below). Finally, note that the effective discount rate for the specific investments is quite high. Apart from the discount rate r, future returns are also discounted with the exogenous separation rate δ, and the limited duration of the match. Hence, specific investments by either party are quite \`risky´, even from a social point of view. Furthermore, ex post bargaining implies that the investor gets only part of the return, further discouraging specific investments.

2.4 Free entry and exit conditions

Next, we consider the free entry of vacancies and the free exit of matches. As noted above, we consider only balanced growth paths where $V(t) = 0 \forall t$. From (2.1) we then have one expression for $J(i_f, i_w, t, t)$

$$J(i_f, i_w, t, t) = \frac{vA(t)}{q(\theta)} + i_f A(t). \qquad (2.15)$$

The sharing rule (2.12) gives us another. Combining the two we get

$$(1-\beta)S(i_f, i_w, t, t) = \frac{vA(t)}{q(\theta)} + i_f A(t) + \alpha_0(f_{sp} + f_c + f_t)A(t). \qquad (2.16)$$

This is the free entry condition, which implicitly gives labour market tightness θ as a function of the other endogenous variables and the parameters. Below we will assume $q'(\theta) < 0$, so to keep the free entry condition satisfied, a fall in the (initial) EPL variables or a rise in the surplus increases θ (ceteris paribus).

Next, consider the exit decision. In our model there is no conflict between the firm and the worker when it comes to separation, given that the firm and the worker can not circumvent EPL. Indeed, from the sharing rules above we note that maximizing (2.10) with respect to $T(t)$ maximizes profits for firms and utility for workers. We find the following condition for the optimal terminal date T(t)

$$\begin{aligned}(c_0 + c_f {i_f}^{\rho_f} + c_w {i_w}^{\rho_w})A(t - T(t)) = {} & (\widetilde{w} + p)A(t) - ((r + \delta - \gamma) \\ & (\alpha_0 + \alpha_1 T(t - T(t))) - \alpha_1) \\ & A(t)(f_c + f_t), \end{aligned} \tag{2.17}$$

after we shift the time index. A match remains in production until the output just covers the (private) `shadow´ value of labour, the unemployment insurance premium and the expected benefits of postponing separation till the next period. In this model, with constant productivity of old matches and ever rising productivity of new matches, the choice is not between separation or no separation, but between separating this period or separating the next period. When I decide to separate the next period there is the advantage that I discount the next period by r and δ. However, postponing separation implies that firing costs and firing taxes will have grown at the rate γ. Furthermore, as we assume a marginal increase of EPL with tenure, this too implies an additional cost of postponing separation equal to $\alpha_1 A(t)(f_c + f_t)$. In the calibration exercise below, the term in front of f_c and f_t will be positive, so that firing costs and firing taxes increase match durations, in line with empirical studies. However, note that if the firing costs or firing taxes rise steeply with tenure at some point, match durations might actually fall due to EPL. Matches will then seek to avert this imminent danger. This is the mechanism at work in models with two-tier EPL regimes, *i.e.* temporary and permanent contracts, where some workers are fired just before they become eligible for a permanent contract.

2.5 Flow equilibrium and balanced budget

We close the model with the flow equilibrium condition for the stocks of employment and unemployment, and the balanced budget condition for the government. We normalize the labour force $L(t)$ to 1 at all dates. Denote the unemployment rate by u. Unemployment is given

$$u(t) = 1 - \int_{t-T(t)}^{t} \theta(\tau) q(\theta(\tau)) u(\tau) e^{\delta(\tau - t)} d\tau. \tag{2.18}$$

Differentiating this expression with respect to time, and then assuming that unemployment is constant along the balanced growth path, we have

$$\theta q(\theta) u = \delta(1-u) + \theta q(\theta) u e^{-\delta T}. \tag{2.19}$$

Match destruction (the right hand side) consists of exogenous match destruction (the first term) and endogenous match destruction (the second term). Rewriting for u we get

$$u = \frac{\delta}{\delta + \theta q(\theta)(1 - e^{-\delta T})}. \tag{2.20}$$

Assuming $\frac{\partial \theta q(\theta)}{\partial \theta} > 0$, this condition illustrates the diverse effects EPL may have on unemployment and hence also employment. Suppose that *e.g.* firing costs reduce both labour market tightness θ and increase match durations T, then the overall effect on unemployment is typically ambiguous.

Finally, the government sets the parameters of EPL, the replacement rate for UI benefits and the level of lump sum transfers (zero in the calibration) and then maintains a balanced budget by varying UI premiums. Assuming the government starts without a debt or surplus, the dynamic budget constraint for the government is

$$\begin{aligned}
&\int_0^\infty \left[\int_{t-T(t)}^t \theta(\tau) q(\theta(\tau)) u(\tau) e^{\delta(\tau - t)} d\tau \, p(t) A(t) + \theta(t - T(t)) \right. \\
&\left. q(\theta(t - T(t))) u(t - T(t)) e^{-\delta T(t)} (\alpha_0 + \alpha_1 T(t)) f_t(t) A(t) \right] e^{-rt} dt \\
&\qquad = \int_0^\infty \left[\left(1 - \int_{t-T(t)}^t \theta(\tau) q(\theta(\tau)) u(\tau) e^{\delta(\tau - t)} d\tau \right) b(t) A(t) \right. \\
&\qquad\qquad\qquad\qquad \left. + y_{ls}(t) A(t) \right] e^{-rt} dt,
\end{aligned} \tag{2.21}$$

unemployment benefits and lump sum transfers have to be financed by either UI premiums or firing taxes. We multiply firing taxes with the number of endogenous match separations in each period, $\theta q(\theta) u$ matches are formed each period of which $e^{-\delta T}$ survive until T.[7]

[7] Matches that are exogenously terminated do not pay EPL. Furthermore, in the absence of firing taxes, along the balanced growth path we simply have the temporal budget constraint

$$p(1 - u) = b_{ui} u + y_{ls}.$$

3 Qualitative analysis of the balanced growth path

In this section we study the balanced growth path more closely. In particular, we first consider the relevance of distinguishing between flat and rising EPL. Flat EPL is often assumed in theoretical work (*e.g.* Mortensen and Pissarides, 1994, and Caballero and Hammour, 1998a). However, most EPL regimes have little or no protection for newly created matches, followed by a gradual build up of EPL with tenure. Next, we consider a second best role for firing taxes[8], given the distortions in the private market outcome.

3.1 The relevance of the tenure profile of EPL

3.1.1 Severance pay

Lazear (1988, 1990) argues that severance pay does not affect job creation or destruction, because a worker and a firm can nullify the severance pay via a private arrangement in case of a separation. Indeed, as shown by Mortensen and Pissarides (1999) and Garibaldi and Violante (2005), an initial wage cut can nullify the effect of severance pay when severance pay is zero for a new match. Below we show that the same is true in our vintage model. However, still of some interest is the effect on the wage profile. We derive an expression for how severance pay affects the wage profile, and show that although overall wages will fall, wages of workers with high tenure may rise.[9]

We already showed that severance pay does not affect the separation decision. Severance pay is a transfer from the firm to the worker, and hence does not affect the surplus of the match (directly). However, it may still affect job creation. Consider the free entry condition (2.16). We study two extreme cases, one where severance pay is flat and one where it is initially zero, both cases resulting in the same severance pay being paid at separation. First, consider the case that initial severance pay is zero, $\alpha_0 = 0$. The surplus of the match, the right hand side of (2.16) is not directly affected by severance pay. Specific investments are also not directly affected since match durations do not change. In that case the \`shadow wage´ is also not affected and hence θ is independent of f_{sp} as well. Since unemployment and the budget constraint only depend on severance pay via θ and T, these variables are also not affected. Hence, in this case severance pay drops out of the equations determining the equilibrium.

Empirically, this seems the relevant case, and neither job creation and destruction are affected by severance pay in our setup. However, what is then still of some interest is the impact of severance pay on the wage profile. Set α_0 to zero and suppose for notational convenience that

[8] And potentially firing costs, although firing taxes would always be preferred in our setup since the firing costs have no direct productive role.

[9] This could motivate a push for higher severance pay by workers with higher tenure, via *e.g.* the political process or trade unions.

$\alpha_1 = 1/T$ so that in period T the expression $\alpha_1 T$ simply becomes 1. We can then derive a path of wages in the following way. First, subtract the expression for $U(t)$ from $E(i_f, i_w, \tau, t)$ and solve the resulting differential equation with terminal condition (2.6) to get[10]

$$E(i_f, i_w, \tau, t) - U(t) = \int_t^{\tau+T(\tau)} (w(i_f, i_w, \tau, s) - \widetilde{w})A(s)e^{-(r+\delta)(s-t)}ds \\ + f_{sp}A(\tau + T(\tau))e^{-(r+\delta)(\tau+T(\tau)-t)}. \tag{3.1}$$

The surplus of the match to a worker in vintage τ at some date $t > \tau$ is the discounted sum of remaining wage payments over the discounted sum of `shadow wages´ plus expected severance payments discounted to t. Let us also briefly ignore specific investments and set productivity of a vintage created at τ simply to $A(\tau)$, ignore unemployment insurance benefits and their associated premiums, and suppose that $f_c = f_t = 0$. The expression for the remaining surplus then becomes

$$S(\tau, t) = \int_t^{\tau+T(\tau)} (A(\tau) - \widetilde{w}A(s))e^{-(r+\delta)(s-t)}ds. \tag{3.2}$$

When we plug this expression into the sharing rule (2.11) we get another expression for $E(\tau, t) - U(t)$, which combined with the expression above gives

$$\int_t^{\tau+T(\tau)} w(\tau, s)A(s)e^{-(r+\delta)(s-t)}ds + f_{sp}(A(\tau + T(\tau))e^{-(r+\delta)(\tau+T(\tau)-t)} \\ - \frac{t-\tau}{T}A(t) = \int_t^{\tau+T(\tau)} (\beta A(\tau) + (1-\beta)\widetilde{w}(s))e^{-(r+\delta)(s-t)}ds. \tag{3.3}$$

We can use (3.3) to show how severance pay affects wage payments during the match. First, consider the date of creation

$$\int_\tau^{\tau+T(\tau)} w(\tau, s)A(s)e^{-(r+\delta)(s-\tau)}ds + f_{sp}(A(\tau + T(\tau))e^{-(r+\delta)T(\tau)} \\ = \int_\tau^{\tau+T(\tau)} (\beta A(\tau) + (1-\beta)\widetilde{w}A(s))e^{-(r+\delta)(s-\tau)}ds. \tag{3.4}$$

Total compensation for workers is a weighted average of the discounted sums of productivity and shadow wages. Furthermore, since the right hand side does not depend on severance pay when $\alpha_0 = 0$, the discounted sum of wages will have to fall to compensate for the discounted value of expected severance payments. Severance pay merely transfers part of the compensation towards the end of the match.

Next, we can derive a path for wages by differentiating (3.3) with respect to t. This gives[11]

$$w(\tau, t) = \beta e^{-\gamma(t-\tau)} + (1-\beta)\widetilde{w} - \frac{(1-(r+\delta-\gamma)(t-\tau))}{T} f_{sp}. \tag{3.5}$$

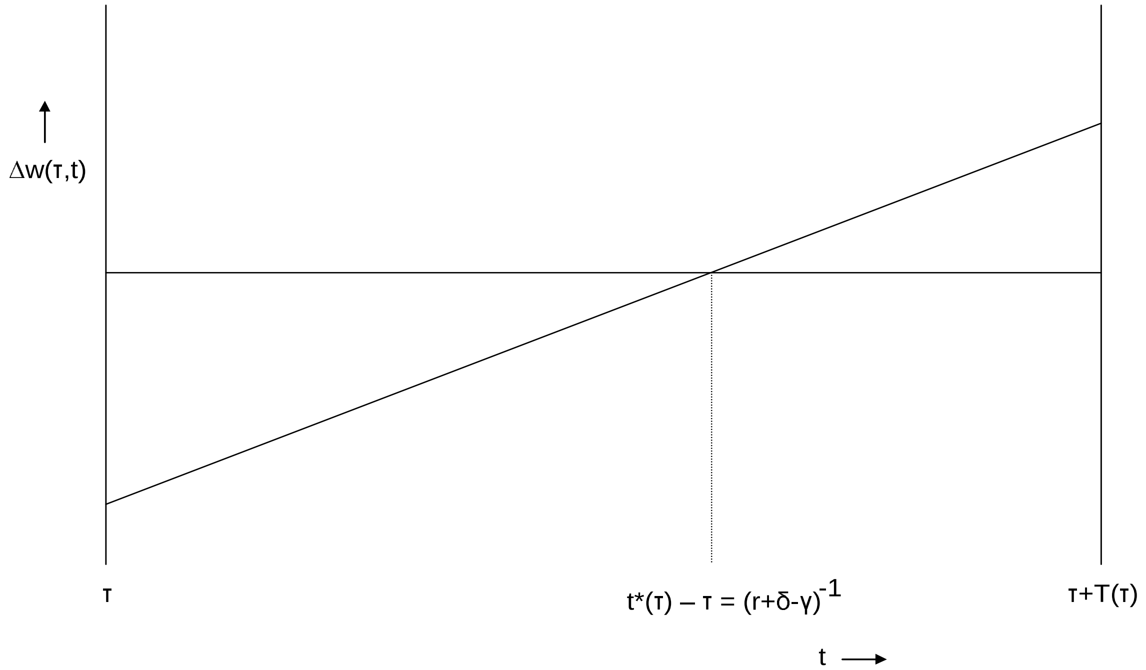
We know from above that the discounted sum of wages has to be lower. At creation we have

$$w(\tau, \tau) = \beta + (1-\beta)\widetilde{w} - \frac{1}{T} f_{sp},$$

[10] Along similar lines as appendix A.1.

[11] Using (3.3) to get rid of the integrals with $r + \delta$.

Figure 3.1 The change in the wage profile due to severance pay



and severance pay leads to lower initial wages. However, in later periods during the match wages may rise. Wages just before destruction are

$$w(\tau,\tau+T) = \beta e^{-\gamma T} + (1-\beta)\widetilde{w} - \frac{1}{T} f_{sp} + (r+\delta-\gamma) f_{sp}.$$

When $r+\delta-\gamma > \frac{1}{T}$ wages eventually rise above the level that would result without severance pay. This is the same condition for firing costs and firing taxes to lengthen match durations, the more relevant case empirically. Indeed, wages will be above the level without severance pay after period $t(\tau)^* - \tau = \frac{1}{r+\delta-\gamma}$ of the match. This is illustrated in Figure 3.1. Severance pay shifts total wages down to keep total compensation constant, but over time severance pay improves the fallback position of workers. This leads to an upward sloping wage profile.[12]

Finally, when α_0 is not equal to zero, severance pay is no longer neutral. Though we think this is empirically less relevant, let us briefly consider how it affects the equilibrium. From (2.16) we can see that severance pay will reduce job creation, θ will have to fall to keep the equality. Furthermore, severance pay will also reduce job creation via a reduction in the surplus resulting from a rise in the \`shadow wage´ $\widetilde{w}$ (conditional on θ). Substitute (2.15) into (2.12) and rewrite to $S(i_f, i_w, t, t)$, substitute into (2.11) to arrive at an expression for $E(i_f, i_w, t, t) - U(t)$, and substitute this into the expression for $\widetilde{w}$ to obtain

$$\widetilde{w} = b_{ui} + b_{ld} + \theta q(\theta)(\alpha_0 f_{sp} + \frac{\beta}{1-\beta}(\frac{v}{q(\theta)} + \alpha_0(f_{sp} + f_t + f_c) + i_f) - i_w). \tag{3.6}$$

[12] Note that wages during the match will also rise due to the rise in \`shadow wages´ resulting from technological progress, which also improves the fallback position of workers.

Conditional on labour market tightness θ, severance pay increases the outside option of workers. Firms have to sink more specific investments into the match, and over the whole employment period workers will benefit from a stronger outside option. The higher shadow wage will deter job creation, and θ will have to fall even more to restore equilibrium.

3.1.2 Firing costs and firing taxes

Next, we show that the tenure profile is also of some relevance for the effects of firing costs and firing taxes, though the differences are less stark then with severance pay. Again, for notational convenience we consider a setup without UI benefits and premiums, no specific investments and in this case no severance pay. We will only study the impact of changes in the tenure profile of firing costs, the impact of changes in the tenure profile of firing taxes on job creation and destruction is similar as long as the receipts from the firing taxes are used for lump sum transfers. Furthermore, for simplicity let us consider the impact of two extreme cases: i) $\alpha_0 = 1$ and $\alpha_1 = 0$ (flat EPL) and ii) $\alpha_0 = 0$ and $\alpha_1 = 1/T_0$ (rising EPL).

First consider job destruction. With the simplifications above we have in the case of flat EPL

$$e^{-\gamma T} = \widetilde{w} - (r + \delta - \gamma) f_c, \tag{3.7}$$

and in case of rising EPL

$$e^{-\gamma T} = \widetilde{w} - (r + \delta - \gamma - \frac{1}{T_0}) f_c. \tag{3.8}$$

As the left hand side depends negatively on T, the effect working via the term $\frac{1}{T_0} f_c$ indicates that the rise in firing costs actually dampens the lengthening effect on match durations. Indeed, postponing job destruction will increase firing costs more in the case of rising firing costs. However, there is an effect working in the other direction, via $\widetilde{w}$. When firing costs are flat, and with the simplifications made above, $\widetilde{w}$ is

$$\widetilde{w} = \theta q(\theta) \frac{\beta}{1-\beta} (\frac{v}{q(\theta)} + f_c), \tag{3.9}$$

but when firing costs are rising and initially zero the f_c term drops out

$$\widetilde{w} = \theta q(\theta) \frac{\beta}{1-\beta} \frac{v}{q(\theta)}. \tag{3.10}$$

So, whether or not rising firing costs lead to more or less job destruction than constant firing costs depends on the increase in firing costs around the terminal date T and the effect running via the outside option of workers $\widetilde{w}$.

Next, consider job creation. With the simplifications made above we have the following free entry condition for flat EPL

$$\frac{v}{q(\theta)} = (1-\beta) \left[\int_t^{t+T} \left(1 - \widetilde{w} e^{\gamma(s-t)} \right) e^{-(r+\delta)(s-t)} ds - e^{-(r+\delta-\gamma)T} f_c \right] - \beta f_c, \tag{3.11}$$

and for rising EPL

$$\frac{v}{q(\theta)} = (1-\beta)\left[\int_t^{t+T}\left(1-\widetilde{w}e^{\gamma(s-t)}\right)e^{-(r+\delta)(s-t)}ds - e^{-(r+\delta-\gamma)T}f_c\right]. \quad (3.12)$$

In the case of flat EPL we have an additional term $-\beta f_c$ on the right hand side. Furthermore, as shown above, conditional on θ the shadow wage $\widetilde{w}$ is also higher with flat EPL. Both the higher initial investment cost and the higher shadow wage deter job creation, and θ will have to fall more in the case of flat EPL than in the case of rising EPL. The flat EPL typically assumed in theoretical work (*e.g.* Caballero and Hammour, 1998a) may therefore overstate the adverse effects of firing costs on job creation.

3.1.3 Empirical support difference severance pay and firing costs

The model above suggests that severance pay does not affect job destruction and creation when new jobs start without severance pay, the empirically relevant case, whereas firing costs later in the match still affect job creation and destruction. Table 3.1 presents some estimation results that support the hypothesis that severance pay is indeed more neutral than firing costs.

For a number of variables, we consider the relation with the overall OECD index for EPL (see OECD, 2004) and then only with the severance pay component. The overall EPL index is a weighted average of subindices for severance pay and notice periods, but also for procedural inconveniences. A difference in the estimates for the overall index and the severance pay variable is then supposed to come from the non severance pay part of the index.[13] We have a value for the OECD index for three periods: the late 1980s, the late 1990s and 2003. Accordingly, we use 5-year averages for the dependent and other control variables to estimate a model with three observations per country.[14] Although the size of the estimated coefficients is not readily comparable, the significance of the estimates may give us some clue as to the relative importance.

We estimate a random effects model and a fixed effects model on the cross-country panel data. The former uses variations between countries and over time to study the relation between the explanatory variables and the dependent variables, the latter only uses the variation within countries over time. The first thing to note is that almost all estimates for the fixed effects model are insignificant, except for the overall EPL index in the equation for the labour force participation rate. Hence, the effects in the random effects models stems from the variation between countries.[15]

[13] The correlation between the overall EPL index and the severance pay variable is .53.

[14] As control variables we used most of the variables suggested by OECD (2004), like spending on active labour market policies as a percentage of GDP, the output gap, the tax wedge, union density, the coverage of collective bargaining and the level of coordination in wage bargaining. Details of the estimated equations are available on request.

[15] Hence, a potential risk in this case is that we are picking up the effect of another (missing) variable that is correlated with both EPL or severance pay and the dependent variables across countries.

Table 3.1 Estimates of the effect of the overall EPL-index and of severance pay on selected labour market variables[a]

Specification[b]	Random effects		Fixed effects	
	Overall index	SP	Overall index	SP
Employment-to-population ratio	– 1.81**	– .35	– 1.50	.92
	(.84)	(.42)	(1.04)	(.59)
Labour force participation rate	– 1.83**	.29	– 1.59*	.92
	(.65)	(.32)	(.80)	(.46)
Unemployment rate	.29	.19	– .36	.04
	(.45)	(.25)	(.57)	(.40)
Duration of unemployment	5.77***	3.40***	2.22	– 2.39
	(.55)	(.32)	(2.95)	(4.89)

[a] We use version 1 of the summary indicator for EPL from the OECD, which is available for the late 1980s, late 1990s and 2003. Version 2 includes additional arrangements for collective dismissals, but version 2 is only available for the late 1990s and 2003. For severance pay we use the average (legislated) severance pay for a worker fired after 9 months, 4 years and 20 years of tenure. These data are also from the OECD. *, ** and *** are used to indicate significance at the 10%, 5% and 1% level, respectively. Standard errors are in brackets. All estimated equations contain a number of (significant) control variables, where the controls are the same for the equations with the OECD indicator and the severance pay variable. Details are available on request.
[b] In the random effects model we assume random country effects (and use feasible generalized least squares), in the fixed effects model we assume fixed country effects.

For the random effects model we find a significant negative relation for the employment-to-population ratio and the labour force participation rate when we use the overall OECD index, but not when we only include the severance pay variable. The effect on unemployment is insignificant for both variables. This suggests that much of the negative effect of EPL on employment runs via a discouraged worker effect, something we take up in an extension of our model in Section 5. Since severance pay does not directly reduce the returns from formal production, it is less distortionary than firing costs.

Severance pay does not seem entirely neutral however, as both the overall index and severance pay are positively correlated with unemployment durations. Indeed, in a setting where we have endogenous search and selection by workers the neutrality of severance pay may break down. Higher severance pay may lead to less search effort, in particular for unemployed that would otherwise run into a liquidity constraint (see Chetty, 2008). The finding may also be indicative of a reverse causation, where longer unemployment durations make workers demand higher severance pay.[16]

[16] Fella (2007) studies the optimal severance pay level and finds that, conditional on the level and duration of unemployment benefits, longer unemployment durations imply a higher optimal severance pay level.

3.2 Social planner and EPL

Next, we study a potential second best role for firing taxes. We first study the social planner outcome, and then consider the private market outcome and how firing taxes may help.

3.2.1 First-best

The social planner solves the following optimisation problem, given the initial distribution of vintages for $\tau < 0$,

$$\begin{aligned}\max_{\{m(t),T(t),i_f(t),i_w(t)\}_{s=0}^{\infty}} \Omega = \int_0^{\infty} (\int_{t-T(t)}^{t} & (c_0 + c_f i_f(\tau)^{\rho_f} \\ & + c_w i_w(\tau)^{\rho_w})A(\tau)m(\tau)e^{\delta(\tau-t)}d\tau \\ & + b_{ld}A(t)u(t) - c(m(t),u(t))A(t) \\ & - m(t)(i_f(t)+i_w(t))A(t))e^{-rt}dt,\end{aligned}$$

$$s.t. \quad u(t) = 1 - \int_{t-T(t)}^{t} m(\tau)e^{\delta(\tau-t)}d\tau, \tag{3.13}$$

where $m(t) \equiv \theta(t)q(\theta(t))u(t)$ is the number of matches in period t and $c(m(t),u(t))$ is the creation cost. Following Caballero and Hammour (1996), this creation cost function can be derived from a matching function in the following way. Let the matching function be given by

$$m = \sigma u^{\phi} j^{1-\phi}, \quad 0 < \phi < 1, \tag{3.14}$$

where j is the number of vacancies. When we rewrite this function to j we have the number of vacancies as a function of the required matches. Given that posting a vacancy costs $vA(t)$ per unit of time we then have search costs for the social planner as

$$c(m(t),u(t))A(t) = \sigma^{-\frac{1}{1-\phi}}(m(t)u(t)^{-\phi})^{\frac{1}{1-\phi}}vA(t). \tag{3.15}$$

Specific investments Using calculus of variations we can determine the optimal specific investments (see appendix A.2)

$$i_f = \left(\frac{c_f\rho_f}{r+\delta}\left(1-e^{-(r+\delta)T}\right)\right)^{-\frac{1}{1-\rho_f}}, \tag{3.16}$$

and

$$i_w = \left(\frac{c_w\rho_w}{r+\delta}\left(1-e^{-(r+\delta)T}\right)\right)^{-\frac{1}{1-\rho_w}}. \tag{3.17}$$

At the optimum, the marginal cost of an additional unit of specific investment equals the discounted sum of the marginal increase in output. A comparison with the private market outcomes (2.13) and (2.14) shows that the social return is higher than the private return. Due to ex post bargaining over the returns of these specific investments, there will be under investment in specific investment by both parties in the private market outcome.

Creation and destruction We can derive optimal job creation and destruction using the methods in Kamien and Muller (1976) for an optimal control problem with integral state equations (see again appendix A.2). When job creation is optimal we have

$$\int_{\tau}^{\tau+T(\tau)} (A(\tau)-(b_{ld}-c_u'(t))A(t))e^{-(r+\delta)(t-\tau)}dt = A(\tau)c_m'(\tau), \tag{3.18}$$

so job creation occurs until the marginal creation cost (the right hand side) equals the discounted stream of productivity minus the social shadow price of labour (the left hand side). The shadow price of labour is the marginal reduction in search costs of having one more unemployed plus the direct (potentially negative) value of unemployment b_{ld}.

Optimal job destruction occurs when

$$A(t-T(t)) = (b_{ld}-c_u'(t))A(t), \tag{3.19}$$

matches are destroyed when the value of production in vintage $t-T(t)$ at time t equals the value of moving an individual to unemployment, the direct value of unemployment and the marginal reduction in search costs of having one additional unemployed.

For the search cost specification (3.15) we have

$$c_u'(t) = -\frac{\phi}{1-\phi}\theta(t)v, \tag{3.20}$$

and

$$c_m'(t) = \frac{1}{1-\phi}\frac{1}{\sigma}\theta(t)^{\phi}v. \tag{3.21}$$

When we compare these expressions with the private market outcomes of (2.16) and (2.17), with $q(\theta)=\sigma\theta^{-\phi}$ from the matching function (3.14), and specific investments would be optimal, we see that the private market outcome coincides with the social optimum when $\beta=\phi$ (see Hosios, 1990, or Pissarides, 1990).

3.2.2 Second-best

However, the private market outcome is not efficient in our setup, even when the Hosios condition is met. First, we have underinvestment in specific investments due to ex post bargaining over the rents from these investments. Second, unemployment insurance benefits and premiums drive a wedge between the social and private value of creating and continuing a match. Firing taxes may then play a second best role. Note that firing taxes only attack the underinvestment problem indirectly, with potential adverse consequences like sclerosis. A more efficient policy response would be to attack the underinvestment directly, for example by making it possible for firms and workers to sign an ex ante contract on the returns of the specific investments. But this is the equivalent to a tin can opener. Indeed, the very nature of the specific investments and their returns make it hard to write a contract on the returns. Both the investment itself, and the returns are hard to observe and hence to verify by a third party.[17]

[17] See also the discussion in Caballero and Hammour (1998b, pp. 730-732).

To simplify matters, we study the second best role of firing taxes for a number of particular values for the parameters, in line with the calibration. Specifically, we set $\alpha_0 = 0$, no initial EPL, and $\beta = \phi = .5$, so that specific investments drop out of the shadow wage of workers $\widetilde{w}$ and the Hosios condition is met (absent other distortions), and $c_w = c_f = c$ and $\rho_w = \rho_f = \rho$ so that specific investment choices are the same $i_w = i_f = i$ for workers and firms.

Underinvestment in specific investments First, consider the second best role of EPL when there is underinvestment in specific investments (see also Belot *et al.*, 2007), and suppose there are no unemployment insurance benefits and premiums $b_{ui} = p = 0$. Since workers only get a share β of the returns to their specific investments, and firms only get a share $1-\beta$ of the returns of their specific investments, both will be too low in the private market outcome, compare (2.13) and (2.14) with (3.16) and (3.17). This may also affect job creation and destruction. For the parameter choices above, the job creation condition becomes

$$\begin{aligned} \frac{v}{q(\theta)} = -i \; &+ \left(\frac{1-e^{-(r+\delta)T}}{r+\delta}\right) ci^{\rho} \\ &+ \frac{1}{2}\left(\frac{1-e^{-(r+\delta)T}}{r+\delta}\right) c_0 \\ &- \frac{1}{2}\left(\frac{1-e^{-(r+\delta-\gamma)T}}{r+\delta-\gamma}(\widetilde{w}+p)\right) \\ &- \frac{1}{2}\left(\alpha_1 T e^{-(r+\delta-\gamma)T} f_t\right), \end{aligned} \tag{3.22}$$

with

$$\widetilde{w} = b_{ld} + \theta v. \tag{3.23}$$

This condition shows that under these assumptions, job creation would actually still be at the optimum, provided T is at the optimum. In this situation, the firm only gets 50% of the returns of his or her own specific investments, making job creation too low. This is however compensated by the 50% of the returns the firm can claim from the specific investments by the worker.

Unfortunately, T will typically not be at the optimum. Indeed, the condition for T becomes

$$e^{-\gamma T} = \frac{\widetilde{w} + p - ((r+\delta-\gamma)\alpha_1 T - \alpha_1) f_t}{c_0 + 2ci^{\rho}}. \tag{3.24}$$

When i is too low, this will make T too low as well, jobs are destroyed too soon. With the return period inefficiently low, this will cause job creation to be inefficiently low. The combination of inefficiently high job destruction coupled with inefficiently low job creation will result in an inefficiently high level of unemployment in the laissez-faire outcome.

Firing taxes can improve the private market outcome. When $(r+\delta-\gamma) > \frac{1}{T}$, firing taxes increase match durations. This is the case in the calibration. It is also in line with the robust empirical finding that higher EPL increases match durations. Hence, by introducing a firing tax we can increase inefficiently low match durations T. This will also raise specific investments, further raising T. The downside of introducing firing taxes is that they deter job creation, see above. However, this depends on what we do with the receipts of the firing tax. If we use the receipts for lump sum transfers, this is indeed the case. However, if we use the receipts to give a per period subsidy $pA(s)$ to matches, we can nullify this effect. Specifically, by choosing

$$\Delta p = -\frac{e^{-(r+\delta-\gamma)T}}{1-e^{-(r+\delta-\gamma)T}}(r+\delta-\gamma)\Delta f_t, \tag{3.25}$$

the introduction of the firing tax will be neutral with respect to job creation (ceteris paribus).[18]

UI benefits and premiums Unemployment insurance benefits and premiums may also provide a rationale for firing taxes (see Blanchard and Tirole, 2008). We keep the simplifying assumptions above, but now assume positive b_{ui} and p initially. The shadow wage of workers becomes

$$\widetilde{w} = b_{ui} + b_{ld} + \theta v. \tag{3.26}$$

Conditional on θ, $\widetilde{w}$ will be higher. Combined with a positive p we can see from the job creation condition (3.22) above, that job creation will be inefficiently low. Also, job destruction will be inefficiently high, the higher shadow wage $\widetilde{w}$ and premiums p lower match durations T, see (3.24). Hence, again unemployment will be inefficiently high in the absence of firing taxes.

As before, firing taxes may improve the private market outcome. The introduction of firing taxes will lengthen match durations, reducing excessive job destruction. Furthermore, this can be achieved without a cost on the creation side by using the receipts from the firing tax for a budgetary neutral shift from firing taxes to lower unemployment insurance premiums.[19]

[18] Note that whether or not firing taxes raise welfare also depends on whether firing costs are present. If so, match durations may be inefficiently high to start with and a firing subsidy rather than a firing tax may be called for.

[19] The remaining distortion on the creation side could in principle be nullified by a further subsidy financed by a lump sum tax, but this is typically (politically) not allowed.

4 Quantitative analysis of the balanced growth path

We continue with a quantitative analysis of the impact of EPL in general equilibrium. We only consider the case where EPL of new matches is zero initially, and rises subsequently with tenure. This seems the empirically relevant case. In this case, severance pay will not affect the equilibrium and hence we do not consider it below. However, we do consider the impact of firing costs and firing taxes, where the latter may be used for lump sum transfers or to reduce UI premiums. To facilitate the discussion later on, we start with some partial derivatives, then discuss the calibration and subsequently the simulation outcomes.

4.1 Equilibrium conditions and partial derivatives

An equilibrium is a consistent set of values for

- specific investments by firms i_f,
- specific investments by workers i_w,
- shadow wage $\widetilde{w}$,
- labour market tightness θ,
- match duration conditional on survival T,
- unemployment u,
- UI premiums p, for given firing taxes f_t.

The equilibrium values for these variables are

$$i_f = \left(c_f \rho_f \frac{1-\beta}{r+\delta}(1-e^{-(r+\delta)T})\right)^{\frac{1}{1-\rho_f}},$$

$$i_w = \left(c_w \rho_w \frac{\beta}{r+\delta}(1-e^{-(r+\delta)T})\right)^{\frac{1}{1-\rho_w}},$$

$$\widetilde{w} = b_{ld} + b_{ui} + \theta\frac{\beta}{1-\beta}v + \theta q(\theta)\left(\frac{\beta}{1-\beta}i_f - i_w\right),$$

$$\begin{aligned}\frac{v}{q(\theta)} = -i_f \ &+ (1-\beta)\left(\frac{1-e^{-(r+\delta)T}}{r+\delta}\left(c_0 + c_f {i_f}^{\rho_f} + c_w {i_w}^{\rho_w}\right)\right) \\ &-(1-\beta)\left(\frac{1-e^{-(r+\delta-\gamma)T}}{r+\delta-\gamma}(\widetilde{w}+p)\right) \\ &-(1-\beta)\left(\alpha_1 T e^{-(r+\delta-\gamma)T}(f_c+f_t)\right),\end{aligned}$$

$$e^{-\gamma T} = \frac{\widetilde{w}+p-((r+\delta-\gamma)\alpha_1 T-\alpha_1)(f_c+f_t)}{c_0 + c_f {i_f}^{\rho_f} + c_w {i_w}^{\rho_w}},$$

$$u = \frac{\delta}{\delta + \theta q(\theta)(1 - e^{-\delta T})},$$

$$p = \frac{b_{ui} u + y_{ls}}{1-u} - \frac{e^{-(r+\delta-\gamma)T}}{1 - e^{-(r+\delta-\gamma)T}} (r + \delta - \gamma) f_t.$$

Table 4.1 gives some partial derivatives. We briefly reiterate some interesting direct effects, or the absence thereof.

Regarding specific investments, what is relevant to note is that both specific investments by the firm and the worker rise with T, whereas specific investments by workers and firms rise respectively fall with the bargaining power of workers β. Furthermore, EPL does not directly affect specific investments, it will only indirectly affect specific investments via the match duration T.

The shadow wage of workers, reflecting the private value of unemployment, depends positively/negatively on the specific investments that firms/workers sink into new matches. However, in the base calibration below we assume that $\beta = .5$ and similar technologies $c_f = c_w$ and $\rho_f = \rho_f$ in which case the specific investment terms cancel in $\widetilde{w}$, and so there will be no indirect effect of specific investments via the shadow wage of workers on job creation and destruction. The job finding rate $\theta q(\theta)$ rises in θ so the $\widetilde{w}$ will rise with labour market tightness as well.

The rate at which vacancies are filled $q(\theta)$ depends negatively on θ, so the left hand side of the job creation condition rises with θ. Since i_f and T are chosen optimally by the firm, the partial derivative of labour market tightness with respect to these variables is zero. However, more specific investments by the worker will increase job creation by the firm. A higher shadow wage has a negative effect on job creation, so a rise in benefits will reduce job creation via the shadow wage, as will UI premiums, firing costs and firing taxes. What is also of interest is that when the bargaining power of workers β increases, the negative effect of firing costs and firing taxes on job creation is actually reduced. A higher β means that you get a larger stake in the surplus, hence you also get a higher stake in factors that reduce the surplus, like firing costs and firing taxes.[20]

The left hand side of the job destruction condition falls with T. Higher specific investments by firms or workers raise productivity, lengthening match durations. A rise in the shadow wage or UI premiums will shorten match durations. Firing costs and taxes will lengthen match durations when $(r + \delta - \gamma) > \frac{1}{T}$. Finally, note that using firing taxes to pay for UI benefits instead of UI premiums (a move towards \`experience rating´) will lengthen matches both because it increases f_t but also because it reduces p.

As noted above, unemployment depends negatively on θ and T. A rise in UI benefits and premiums will lower both θ and T via its effect on $\widetilde{w}$, and hence will unambiguously raise

[20] In the case with initial EPL as in (2.27), there is a counteracting negative effect on job creation from a rise in β through firing costs and firing taxes (as well as severance pay). So, again the tenure profile of EPL makes a difference.

Table 4.1 Partial derivatives

	Variables					Parameters				
	i_f	i_w	$\widetilde{w}$	θ	T	β	b_{ui}	p	f_c	f_t
i_f	.	0	0	0	+	–	0	0	0	0
i_w	0	.	0	0	+	+	0	0	0	0
$\widetilde{w}$	+	–	.	+	0	+	+	0	0	0
θ	0	+	–	.	0	–	0[a]	–	–	–
T	+	+	–	0	.	0	0[a]	–	?[b]	?[b]
p	0	0	0	–	–	0	+	.	0	?[c]
u	0	0	0	–	–	0	0	0	0	0

[a] Higher benefits b_{ui} will decrease θ and T indirectly via their effect on $\widetilde{w}$.
[b] $\frac{\partial T}{\partial f_c}, \frac{\partial T}{\partial f_t} > 0$ when $r + \delta - \gamma > \frac{1}{T}$.
[c] 0 when firing taxes are used for lump sum transfers, – when firing taxes are used to reduce UI premiums.

unemployment. However, a rise in firing costs may reduce both job creation and destruction, making the overall effect on unemployment ambiguous.

4.2 Calibration

We calibrate the model on data and studies for the Dutch labour market, for different levels of specific investments. The relevant data, assumptions and calibrated parameters, for the case where specific investments make up a large part of total productivity, are given in Table 4.2.

We use the (annual) stock and flow data from Kock (2002) for the period 1991-1997. These data are somewhat dated, but consistent. The unemployment rate is .065, the outflow rate (not probability) from unemployment to employment is .87, which together in steady state imply a match destruction rate of .06. As an indicator of the share of matches that is exogenous and to which EPL does not apply we take one minus the share of job creation and destruction in gross worker flows, which is about .3 for the period 1991-1997 according to Kock (2002). The motivation for this is that worker flows in excess of job flows are worker initiated separations, to which employment protection typically indeed does not apply. We set $\delta = .018$ for the exogenous match destruction rate. Then we rewrite the flow equilibrium condition (2.20) to get $T = -\frac{1}{\delta} \ln \left(1 - \frac{1-u}{u} \frac{\delta}{\theta q(\theta)}\right)$, which implies a $T = 19.6$ will generate the required amount of endogenous match destruction. We use b_{ld} to calibrate this value for T, which turns out to be .058.

We assume constant returns to scale in the matching technology, and an elasticity of matches with respect to unemployment ϕ of .5, which falls in the range of empirical estimates reported by *e.g.* Broersma and van Ours (1999). We calibrate the efficiency parameter in the matching process σ so that the job finding rate corresponds with the data on labour market tightness and ϕ above. Labour market tightness is set in line with the data. Rewriting the expression for labour

Table 4.2 Calibration of the case with large specific investments

Data		Assumptions	
Unemployment rate u	.065	Share prod. from firm spec. inv.	.125
Outflow rate $\theta q(\theta)$	.057	Share prod. from worker spec. inv.	.125
Maximum match duration T	19.6	Ave. private return spec. inv.	.125
Exogenous job destruction rate δ	.018	Rel. bargaining power of workers β	.500
Labour market tightness θ	.268	Initial lump sum transfer y_{ls}	.000
Discount rate firms/workers r	.050		
Benefits in unemployment b_{ui}	.500		
Matching weight unempl. ϕ	.500		
Rate of technological progress γ	.013		
Firing costs f_c	.100		
Initial EPL α_0	.000		
Calibrated parameters			
Decreasing returns parameter ρ_f	.739	Deceasing returns parameter ρ_w	.739
Share parameter spec. inv. firms c_f	.209	Share param. spec. inv. workers c_w	.209
Per period vacancy costs v	.710	Constant matching function σ	1.68
Unemployment benefits premium p	.035	Direct utility of unemployment b_{ld}	.058
Slope of tenure profile of EPL α_1	.051		

market tightness to v, and we find a per period vacancy posting cost of .71 (normalising initial productivity to 1, see below).

We assume that the discount factor is .05. Furthermore, since we assume that workers and firms have the same discount factor, $\beta = .5$ is a natural choice for the relative bargaining power of workers (see *e.g.* Rubinstein, 1982, and Layard *et al.*, 1991). This choice for β implies that in the absence of distortions in specific investments or distortions due to unemployment benefits and its financing, the market solution will coincide with the social planner solution (see above). The benefit level is set to .5, unemployment being made up of individuals receiving more generous unemployment benefits and individuals receiving less generous unemployment assistance, and the wage being below productivity with the productivity of new matches normalized to 1. This is including the additional productivity resulting from specific investments (so in all simulations below initial productivity of new matches is the same).

Regarding productivity growth, average productivity growth has been around 1.5% per annum since the mid 1970s (see CPB, 2008, Chapter 5) and also over the past decade up to the crisis. In their analysis of France, Caballero and Hammour (1998) assume that all technological progress is `embodied´, and they ignore disembodied technological progress. This is potentially not innocuous, as the extent to which EPL might lead to technological sclerosis will depend on the extent to which technological progress is embodied or disembodied. However, the assumption that most if not all technological progress is embodied seems a reasonable approximation for the Dutch data as well, though our empirical knowledge on this is rather dated.[21] Kuipers *et al.* (1979) find for the period 1948-1976 that embodied technological progress makes up 78% of total productivity growth. Gelauff *et al.* (1985) find for the period 1960-1982 that all technological progress is embodied in the long run.[22] These empirical studies suggest that almost all technological progress is embodied, hence we set the growth rate of (embodied) technological progress γ to .0125 in the calibration, slightly below the per annum average growth of productivity since the mid 1970s.

Next, consider the calibration of the return to specific investments and the contribution of specific investments to total productivity of a match. The average private return to specific investment by firms and workers in the model is given by $r_f^{si} = (1-\beta)c_f i_f^{\rho_f - 1} = \frac{1}{\rho_f}\frac{1-e^{-(r+\delta)T}}{r+\delta}$ and $r_w^{si} = \beta c_w i_w^{\rho_w - 1} = \frac{1}{\rho_w}\frac{1-e^{-(r+\delta)T}}{r+\delta}$, respectively. We use these expressions to calibrate ρ_f and ρ_w, which captures the diminishing returns to productivity of a marginal unit of specific investments. Rewriting to ρ_f and ρ_w gives $\rho_f = \frac{1}{r_f^{si}}\frac{1-e^{-(r+\delta)T}}{r+\delta}$ and $\rho_w = \frac{1}{r_w^{si}}\frac{1-e^{-(r+\delta)T}}{r+\delta}$. The last term in these expressions shows that the private return has to be quite high, because there is an exogenous risk that matches end and matches that do survive are still terminated after T periods. With the values of r, δ and T in the calibration the last term becomes .092. For bounded specific investments we need $\rho_f, \rho_w < 1$, so the private return has to be above this. We pick a value for $\rho_w = \rho_f = .739$, to keep specific investments bounded and to generate an average private return rate of .125.[23] Is this a reasonable number? Perhaps the returns on workplace training are informative on this. Like the specific investments we consider, these investments also face at least the additional risk of limited return periods. Bassanini *et al.* (2005) estimate the private returns to workplace training, using data from the European Community Household Panel for the period 1995-2001. The average over all countries is a return of 9.1% using OLS and 2.5% assuming fixed effects (see Bassanini *et al.*, 2005, Table 4.2). This suggests that our value may be a bit high, but then again workplace training may also result in general skills which extend beyond the duration of the match.

We calibrate the contribution of specific investments to total productivity of a match using c_f and c_w. Again, our knowledge on the potential size of this is limited. Topel (1990) suggests that displaced workers earn on average some 10 to 20% lower wages in their new job compared to their old job, which may be an indication of the quasi-rents earned by workers due to match specific human capital. Our strategy is to try different values for this share, and see for which

[21] From the previous time that vintage models were fashionable, before they were (at least temporarily) revived by Caballero and Hammour starting with Caballero and Hammour (1994). However, again interest seem to have waned, perhaps again due to their complexity, consider *e.g.* the following quote from Blanchard (2000, p. 1403) on Caballero and Hammour (1996) (and Phelps, 1994):"[T]hese are important contributions, but I see them more as the prototype cars presented in car shows but never mass produced later: they show what can be done, but they are probably not exactly what will be."

[22] Actually, they restrict the parameter of disembodied technological progress to 0 in the estimation, otherwise it would presumably become negative, which seems implausible.

[23] Note that the social return is twice the private return, as firms and workers only get half of their specific investment due to ex post bargaining.

values the effect of EPL via specific investments on productivity dominates the effect EPL has on productivity via reduced reallocation. In our first calibration we assume that specific investments by firms and workers both contribute a share $s = .125\%$ to total productivity of the match. We then fill in the numbers in $c_f i_f^{\rho_f} = s \Rightarrow c_f = s^{1-\rho_f}\left((1-\beta)\rho_f \frac{1-e^{-(r+\delta)T}}{r+\delta}\right)^{-\rho_f}$ and $c_w i_w^{\rho_w} = s \Rightarrow c_w = s^{1-\rho_w}\left(\beta\rho_w \frac{1-e^{-(r+\delta)T}}{r+\delta}\right)^{-\rho_w}$. Workers can claim 50% of the specific investments by the worker and the firm. As a result, this makes up some 12.5% of their wages.

Finally, for firing costs we use the data on EPL paid by firms collected by Knegt and Tros (2007). One of the interesting aspects of their study is that they decompose total `firing expenditures´ into transfers to workers and costs of administrative and legal procedures. The average firing expenditure was in the order of 17 thousand euro in 2007. Of this, administrative and legal procedures only make up about 2.5 thousand euro. The modal wage was in the order of 30 thousand euro in 2007 in The Netherlands, and so we set firing costs f_c to .1 in the base calibration. We further assume that initial EPL is zero, $\alpha_0 = 0$, and there are no firing taxes or lump sum transfers in the base calibration.

4.3 Simulations

We consider the effect of three types of reforms: i) reducing or increasing firing costs, ii) introducing firing taxes to pay for lump sum transfers, iii) introducing firing taxes to reduce UI premiums. We first consider how these reforms work out when specific investments are important. Next we consider what happens when they are somewhat less important, and finally when they play no role at all .[24]

4.3.1 Underinvestment in specific investments

We first consider the case that specific investments make up a large part of productivity, 25%, the calibration discussed above. Table 4.3 gives the percentage changes that result from a change in firing costs. Note that firing costs are .1 initially, hence the zeros in the second row. We discuss the effects on the variables from left to right.

Reducing firing costs to zero (the top row) leads to shorter match durations T. As a result, the job destruction rate goes up, in line with empirical studies. Labour market tightness θ drops, and hence the job finding rate goes down. On the one hand, lower firing costs lead to a direct reduction in labour costs, making it more profitable to post vacancies. On the other hand, shorter match durations discourage specific worker investments into the match, part of which is claimed by firms via ex post bargaining, reducing the profitability of the match. The latter effect

[24] The latter also being indicative of the case where no contracting problems exist regarding the returns on specific investments.

Table 4.3 Firing cost, specific investments 25% of productivity, %-changes[a]

f_c (level)	T	JD rate	θ	JF rate	u	e	$i_f \& i_w$	Q/E	Q	W
.0	– 5.1	4.5	– 3.5	– 1.8	6.0	– .4	– 9.4	– 1.2	– 1.6	– 0.9
.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.2	5.3	– 4.2	3.5	1.7	– 5.4	.4	9.7	1.2	1.6	0.8
.3	10.7	– 8.1	6.9	3.4	– 10.4	.7	19.5	2.4	3.1	1.6
.4	16.3	– 11.7	10.2	5.0	– 15.0	1.0	29.6	3.5	4.6	2.4
.5	22.0	– 15.0	13.5	6.5	– 19.2	1.3	39.7	4.6	6.0	3.1
.6	27.9	– 18.2	16.7	8.0	– 23.0	1.6	49.8	5.7	7.3	3.8

[a] The variables are from left to right: firing costs normalized by leading edge technology, maximum match durations conditional on survival until T, the job destruction rate, labour market tightness, the job finding rate, unemployment, employment, specific firm investments, specific worker investments, productivity, gross output and welfare.

Table 4.4 Firing taxes to pay for lump sum transfers, specific investments 25% of productivity, %-changes[a]

f_t (level)	T	JD rate	θ	JF rate	u	e	$i_f \& i_w$	Q/E	Q	W
.1	5.3	– 4.2	3.5	1.7	– 5.5	.4	9.7	1.2	1.6	1.3
.2	10.7	– 8.1	6.9	3.4	– 10.4	.7	19.5	2.4	3.1	2.7
.3	16.3	– 11.7	10.2	5.0	– 15.0	1.0	29.6	3.5	4.6	3.9
.4	22.0	– 15.0	13.5	6.5	– 19.2	1.3	39.7	4.6	6.0	5.1
.5	28.0	– 18.2	16.7	8.0	– 23.0	1.6	49.9	5.7	7.3	6.3

[a] The variables are from left to right: firing taxes normalized by leading edge technology, maximum match durations conditional on survival until T, the job destruction rate, labour market tightness, the job finding rate, unemployment, employment, specific firm investments, specific worker investments, productivity, gross output and welfare.

Table 4.5 Firing taxes to reduce UI premiums, specific investments 25% of productivity, %-changes[a]

f_t (level)	p	T	JD rate	θ	JF rate	u	e	$i_f \& i_w$	Q/E	Q	W
.1	.030	5.7	– 4.5	5.3	2.6	– 6.5	.5	10.4	1.3	1.8	1.5
.2	.025	11.4	– 8.6	10.2	5.0	– 12.2	.8	20.8	2.5	3.4	2.9
.3	.021	17.3	– 12.3	14.9	7.2	– 17.2	1.2	31.3	3.7	4.9	4.2
.4	.017	23.2	– 15.6	19.4	9.3	– 21.6	1.5	41.6	4.8	6.4	5.4
.5	.014	29.2	– 18.8	23.6	11.2	– 25.7	1.8	52.0	5.9	7.7	6.6

[a] The variables are from left to right: firing taxes normalized by leading edge technology, the UI premium rate maximum match durations conditional on survival until T, the job destruction rate, labour market tightness, the job finding rate, unemployment, employment, specific firm investments, specific worker investments, productivity, gross output and welfare.

Table 4.6 Firing cost, specific investments 12.5% of productivity, %-changes[a]

f_c (level)	T	JD rate	θ	JF rate	u	e	$i_f \& i_w$	Q/E	Q	W
.0	– 2.4	2.1	.1	.0	1.9	– .1	– 4.4	– .2	– .3	.2
.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.2	2.6	– 2.1	.0	.0	– 2.0	.1	4.7	.2	.3	– .2
.3	5.3	– 4.2	.0	.0	– 4.0	.3	9.8	.3	.6	– .4
.4	8.3	– 6.4	.0	.0	– 6.0	.4	15.2	.5	.9	– .5
.5	11.5	– 8.6	.1	.1	– 8.2	.6	21.0	.7	1.3	– .7
.6	15.0	– 10.8	.3	.1	– 10.3	.7	27.2	.9	1.6	– .8

[a] The variables are from left to right: firing costs normalized by leading edge technology, maximum match durations conditional on survival until T, the job destruction rate, labour market tightness, the job finding rate, unemployment, employment, specific firm investments, specific worker investments, productivity, gross output and welfare.

Table 4.7 Firing taxes to pay for lump sum transfers, specific investments 12.5% of productivity, %-changes[a]

f_t (level)	T	JD rate	θ	JF rate	u	e	$i_f \& i_w$	Q/E	Q	W
.1	2.6	– 2.1	.0	.0	– 2.0	.2	4.7	.2	.3	.3
.2	5.3	– 4.2	.0	.0	– 4.0	.3	9.8	.3	.6	.7
.3	8.3	– 6.4	.0	.0	– 6.0	.4	15.2	.5	.9	1.0
.4	11.5	– 8.6	.1	.1	– 8.2	.6	21.0	.7	1.3	1.4
.5	15.0	– 10.8	.3	.1	– 10.3	.7	27.2	.9	1.6	1.7

[a] The variables are from left to right: firing taxes normalized by leading edge technology, maximum match durations conditional on survival until T, the job destruction rate, labour market tightness, the job finding rate, unemployment, employment, specific firm investments, specific worker investments, productivity, gross output and welfare.

Table 4.8 Firing taxes to reduce UI premiums, specific investments 12.5% of productivity, %-changes[a]

f_t (level)	p	T	JD rate	θ	JF rate	u	e	$i_f \& i_w$	Q/E	Q	W
.1	.031	2.8	– 2.3	0.7	.3	– 2.4	.2	5.1	.2	.3	.4
.2	.028	5.8	– 4.5	1.4	.7	– 4.9	.3	10.5	.4	.7	.7
.3	.024	9.0	– 6.8	2.1	1.0	– 7.3	.5	16.3	.6	1.1	1.1
.4	.021	12.4	– 9.2	2.8	1.4	– 9.8	.7	22.5	.7	1.4	1.5
.5	.018	16.0	– 11.5	3.5	1.7	– 12.3	.9	29.1	.9	1.8	1.9

[a] The variables are from left to right: firing taxes normalized by leading edge technology, the UI premium rate, maximum match durations conditional on survival until T, the job destruction rate, labour market tightness, the job finding rate, unemployment, employment, specific firm investments, specific worker investments, productivity, gross output and welfare.

dominates in this calibration.[25]

With a higher firing rate and a lower job finding rate, unemployment goes up and employment (e) goes down. Output goes down even further since productivity declines along with employment. On the one hand, productivity rises with shorter match durations, as older vintages are scrapped sooner. On the other hand, firms and workers sink less specific investments into these shorter matches, leading to an overall fall in productivity. Welfare - measured as output minus search costs and specific investment costs plus the utility component in unemployment b_{ld} times unemployment - falls with output. However, the drop is less severe than the drop in output, due to the drop in search and investment costs.

When we increase firing costs, and there is a big underinvestment problem in specific investments, we get the reverse effects. Job durations increase and the job finding rate goes up, reducing unemployment and increasing employment. Higher specific investments further boost output, with welfare rising somewhat less due to the higher investments costs.

Table 4.4 gives the impact of introducing firing taxes, the proceeds of which go to lump sum transfers. We can compare the first row in Table 4.4 with the third row in Table 4.3; both imply a rise in the firing cost to the individual firm of .1. The results are (virtually) identical, except for welfare. Since the firing tax is paid out as lump sum transfers they do not reduce welfare, hence the rise in welfare is larger in the case of firing taxes than in the case of firing costs.

Things work out even better when we give back the firing taxes in the form of a reduction in the UI premium, see Table 4.5. The firing tax reduces the distortion on the destruction margin from UI premiums and benefits. With the UI premium falling, match durations increase even further than in the case above, leading to even higher specific investments. Using the receipts to reduce the UI premium further boosts job creation. Job creation rises more, unemployment falls more, employment rises more, as do productivity, output and welfare.

Tables 4.6-4.8 give the results for the case that specific investments make up 12.5% of total productivity, half of the calibration discussed above. From Table 4.6 we see that in this case we still have rising employment and productivity with higher firing costs. However, job creation hardly changes, the rise in specific worker investments is just making it more profitable to open up more vacancies despite the direct rise in labour costs due to firing costs. Gross output still rises, but welfare now falls as an increasing part of it is wasted on firing costs. Table 4.7 shows that firing taxes, on the contrary, can still improve welfare, while Table 4.8 shows that this is even more likely when the firing taxes are used to reduce UI premiums.

[25] Again, note that since firms pick their own specific investments and set the match duration, there is no direct effect of a change in these variables on job creation.

Table 4.9 Firing cost, no specific investments, %-changes[a]

f_c (level)	T	JD rate	θ	JF rate	u	e	Q/E	Q	W
.0	– 1.6	1.4	.4	.2	1.1	– .1	.2	.1	.5
.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
.2	1.7	– 1.4	– .3	– .2	– 1.1	.1	– .2	– .1	– .5
.3	3.5	– 2.8	– .7	– .3	– 2.3	.2	– .4	– .2	– 1.0
.4	5.4	– 4.3	– 1.0	– .5	– 3.5	.2	– .6	– .3	– 1.5
.5	7.4	– 5.7	– 1.4	– .7	– 4.8	.3	– .8	– .4	– 2.0
.6	9.6	– 7.3	– 1.7	– .8	– 6.1	.4	– 1.0	– .6	– 2.6

[a] The variables are from left to right: firing costs normalized by leading edge technology, maximum match durations conditional on survival until T, the job destruction rate, labour market tightness, the job finding rate, unemployment, employment, productivity, gross output and welfare

Table 4.10 Firing taxes to pay for lump sum transfers, no specific investments, %-changes[a]

f_t (level)	T	JD rate	θ	JF rate	u	e	Q/E	Q	W
.1	1.7	– 1.4	– .3	– .2	– 1.1	.1	– .2	– .1	.01
.2	3.5	– 2.8	– .7	– .3	– 2.3	.2	– .4	– .2	.02
.3	5.4	– 4.3	– 1.0	– .5	– 3.5	.2	– .6	– .3	.02
.4	7.4	– 5.7	– 1.4	– .7	– 4.8	.3	– .8	– .4	.02
.5	9.6	– 7.3	– 1.7	– .8	– 6.1	.4	– 1.0	– .6	.01

[a] The variables are from left to right: firing taxes normalized by leading edge technology, maximum match durations conditional on survival until T, the job destruction rate, labour market tightness, the job finding rate, unemployment, employment, productivity, gross output and consumption.

Table 4.11 Firing taxes to reduce UI premiums, no specific investments, %-changes[a]

f_t (level)	p	T	JD rate	θ	JF rate	u	e	Q/E	Q	W
.1	.031	1.8	– 1.5	.1	.0	– 1.4	.1	– .2	– .1	.02
.2	.028	3.8	– 3.0	.2	.1	– 2.9	.2	– .4	– .2	.04
.3	.025	5.8	– 4.6	.2	.1	– 4.4	.3	– .6	– .3	.05
.4	.022	8.0	– 6.2	.3	.1	– 5.9	.4	– .8	– .4	.05
.5	.019	10.3	– 7.8	.3	.2	– 7.5	.5	– 1.1	– .5	.04

[a] The variables are from left to right: firing taxes normalized by leading edge technology, the UI premium rate, maximum match durations conditional on survival until T, the job destruction rate, labour market tightness, the job finding rate, unemployment, employment, productivity gross output and welfare.

4.3.2 No specific investments

Tables 4.9-4.11 give the effects when we abstract from specific investments to raise productivity. Without specific investments, we are essentially back in the world of Caballero and Hammour (1998a). Table 4.9 shows that higher firing costs now lead to lower productivity: more workers are in less productive vintages. Furthermore, without the countereffect of higher specific worker investments, overall labour costs rise due to higher firing costs, reducing labour market tightness and hence job creation. Unemployment still falls, and employment still rises, with firing costs (in an extension with endogenous labour supply, we can also get a negative effect on employment, see below). The drop in productivity dominates the rise in employment, leading to a fall in output. Welfare falls even more, due to the loss of output to firing costs.

Table 4.10 shows that even in the absence of specific investments, firing taxes can increase welfare, despite the fall in job creation. Indeed, UI benefits and premiums cause firms and workers to separate when the social value of a job is still above the private value. Firing taxes reduce this wedge, with some collateral damage on the creation margin. Output still falls, but not welfare. In the calibration without specific investments, the additional utility term in unemployment b_{ld} is negative, and hence there is an additional benefit from keeping individuals in jobs, leading to a rise in welfare even though output falls. Note that at a high enough value of the firing tax, the welfare effect starts to fall again (indeed, at $f_t = .6$ the welfare effect actually becomes negative, not shown in the table), and lengthening job matches excessively makes firms and workers continue jobs for which the social value is actually less than the private value.

As before, Table 4.11 shows that the welfare effects of firing taxes are more favourable when the receipts are used to reduce UI premiums. But again, there is a limit to the extent to which such a scheme can improve welfare. At some point before UI premiums become zero (`full experience rating´), social welfare is maximized (conditional on the presence of UI benefits). We should note that the welfare gains of a move towards such an `experience rating´ scheme is rather small, <.1%. Replacing firing costs with firing taxes leads to a much bigger welfare gain in this calibration, in the order of .5% looking at Tables 4.9 and 4.11. This seems particularly relevant for the Netherlands, which scored `number 1´ in terms of `procedural inconveniences´ according to the OECD in 2003 (OECD, 2004).

4.3.3 Endogenous labour force participation

Finally, we consider the outcomes for the firing costs simulations when we endogenise labour force participation. We do so mainly to show that the positive effect of a rise in firing costs on employment in the analyses above is not robust, in line with empirical studies.

We endogenise labour force participation along the lines suggested by Pissarides (1990). We assume there is a uniform distribution of discounted lifetime utilities outside the formal labour market running from $\underline{U(t)}$ to $\overline{U(t)}$. Labour force participation is then found by summing all individuals that have a higher utility in the formal labour market than outside the formal labour

Table 4.12 Firing cost, no specific investments, endogenous labour force participation, %-changes[a]

f_t (level)	T	JD rate	θ	JF rate	u	e	part	Q/E	Q
.0	– 1.6	1.4	.4	.2	1.1	1.0	1.0	.2	1.1
.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
.2	1.7	– 1.4	– .3	– .2	– 1.1	– .9	– 1.0	– .2	– 1.1
.3	3.5	– 2.8	– .7	– .3	– 2.3	– 1.9	– 2.0	– .4	– 2.2
.4	5.4	– 4.3	– 1.0	– .5	– 3.5	– 2.8	– 3.0	– .6	– 3.3
.5	7.4	– 5.7	– 1.4	– .7	– 4.8	– 3.7	– 4.0	– .8	– 4.4
.6	9.6	– 7.3	– 1.7	– .8	– 6.1	– 4.5	– 4.9	– 1.0	– 5.5

[a] The variables are from left to right: firing costs normalized by leading edge technology, maximum match durations conditional on survival until T, the job destruction rate, labour market tightness, the job finding rate, unemployment rate, employment, participation rate, productivity and gross output.

market. Note that the marginal individual will always be an unemployed worker, as employed workers earn quasi-rents. Also note that all flow rates are scale independent. Labour force participation will be given by $\frac{U(t)-\underline{U(t)}}{\overline{U(t)}-\underline{U(t)}}$. Solving the differential equation (2.4) for $U(t)$ we have $U(t) = \frac{\left(b_{ui}+b_{ld}+y_{ls}+\frac{\beta}{1-\beta}\theta v\right)}{r-\gamma}A(t)$. By choosing $\underline{U(t)}$ and $\overline{U(t)}$ appropriately relative to $U(t)$, we can calibrate the initial gross participation rate to .7, as in 2007 in the Netherlands for individuals aged 15-64 (CPB, 2008). Furthermore, by moving them closer to or further from $U(t)$ pro rata, we can calibrate the labour force participation elasticity with respect to a change in employment protection, via its effect on the value of unemployment. This exercise is merely an illustration, we choose a value of .01 for this elasticity. Estimates of the effect of EPL on labour force participation suggest an elasticity of around .04 (see Deelen *et al.*, 2006). Our fixed effects estimate in Section 3 also comes close to this. However, this would result in an unrealistic large drop in participation of 4 percent when we increase firing costs from .1 to .2. Hence, we take a more modest value.

Table 4.12 shows the results of this exercise. The effect on the flow rates is still the same, and the unemployment rate still falls with higher firing costs. However, employment now falls with higher firing costs. Higher firing costs reduce the value of participation in the formal labour market, reducing the value of an unemployed individual. Hence, some individuals will switch to the informal labour market, leading to a drop in employment and magnifying the drop in formal output. Welfare will fall less though (not in the table), as individuals now have an escape route. Hence, with the proper modifications, the model can also reproduce the finding in some empirical papers that firing costs reduce formal employment due to a fall in labour force participation.

5 Limitations of the analysis

Severance pay is neutral in our vintage model setup when initial severance pay is zero. It would be interesting to consider severance pay, and potentially notice periods, in a model where they can play a productive role (and may no longer be neutral). Pissarides (2001, 2004) and Fella (2007) provide interesting examples. However, they do not consider specific investments to raise the productivity of a match and assume that UI benefits are exogenous, which still leaves the story incomplete.

Another limitation of our analysis is that we do not consider temporary shocks, either idiosyncratic or business cycle shocks, during which EPL may have an important effect as well. The Mortensen and Pissarides (1994) model has idiosyncratic and business cycle shocks, but they assume that productivity can jump to any value in a given distribution, which seems at odds with productivity patterns. Perhaps a random walk model (see Bentolila and Bertola, 1990, and Shimer, 1999) with growing initial productivity of new matches and a business cycle could show all the different sides that EPL has on job destruction and job creation, also during business cycles. In general, it seems fruitful to work out the different mechanisms at work in the different models of EPL: vintage models, Mortensen-Pissarides models and random walk models.

Another interesting side of EPL that is not captured in our model is its effect on job-to-job flows. It would be interesting to study the so-called golden chains from EPL rights that are not portable from one employer to the next. This may in part explain the rather low `dynamics´ in the market for older workers in the Netherlands (WRR, 2007).

We could perhaps also explore more flexible forms of EPL with tenure. Assuming that severance pay rises linearly with tenure seems close to the truth in the Netherlands. However, the same is probably not true for firing costs (and we do not have firing taxes in the Netherlands). However, this is not that important for the analysis above. What is important is that firing costs are zero initially and then higher later on, but without a sudden jump close to the terminal date.[26] However, if we extend the model to include `experimentation´ initially (uncertainty about match specific productivity), the whole time profile of EPL becomes important, and initial EPL may not only be damaging due to higher wages but also because of the additional cost involved in reduced experimentation.

What is still of some interest is the dual face of Dutch EPL, with strict EPL for permanent contracts but a rather liberal stance towards temporary work and fixed term contracts (see Deelen *et al.*, 2006). It would be interesting to study the coexistence of temporary and permanent contracts, as in *e.g.* Cahuc and Postel-Vinay (2002), Alonso-Borrego *et al.* (2005) and Osuna (2005). We do allow for a gradual build up of EPL, but the model does not feature the

[26] Note that firing costs lengthen job matches in our model because it is actually cheaper to fire later rather than sooner. Hence, assuming that firing costs do not rise with tenure at the separation date actually makes the effect of firing costs on job durations bigger.

discontinuous jump in EPL that occurs when a worker moves from a temporary to a permanent contract, and the resulting churning of workers. For an empirical analysis of temporary work and fixed term contracts in the Netherlands see Zijl (2006). She finds that temporary contracts in the Netherlands act neither as `stepping stone´ nor as `dead-end jobs´, but do reduce unemployment durations.

For the Dutch case it also seems interesting to work out why certain firms choose to take the administrative route via government agencies that can approve dismissal, and other firms choose the route via the court (see Deelen *et al.*, 2006). We may then consider the effects of partial reform, *e.g.* closing one route.

It would also be interesting to consider how the story changes when we assume different wage determination processes, like wage posting by firms and union bargaining. Furthermore, it would be fruitful to consider political economy effects (Saint-Paul, 2002) running via *e.g.* the government or trade unions.

Clearly, there are many more avenues we could explore. Allowing for labour and capital substitution can mitigate the impact of firing costs on output, as shown in Caballero and Hammour (1998a). We could also consider a setup where the specific investments by firms and workers are complementary, and perhaps the underinvestment problem does not appear. We might consider worker heterogeneity, *e.g.* younger and older workers, or low and high skilled workers *etc.* Furthermore, an interesting topic is also the transition path from one balanced growth path to the other, as in *e.g.* Caballero and Hammour (1998a). Indeed, many topics for future research on EPL remain.

6 Concluding remarks

In this paper we consider a number of reasons why the impact of employment protection on both employment and productivity is ambiguous in empirical work. First, lumping together different types of EPL, as in the OECD indicator, may be a poor empirical strategy. Different types of EPL have different effects, and we provide some empirical support for this. Second, when there is underinvestment in firm specific human capital, EPL may enhance productivity as sometimes found in empirical work, despite the sclerosis it creates in the production structure.

We further show that severance pay is neutral in our vintage setup, when initial severance pay is zero. However, an interesting implication of rising severance pay with tenure is that it tilts the wage profile. Wages of new hires fall and wages of workers with long tenures rise, potentially creating a political economy problem. Furthermore, we have shown that firing costs rising with tenure, popular in practice, are less detrimental to job creation than firing costs that are constant with tenure, popular in theoretical work. As a result previous calibration exercises may have overstated the detrimental effect of firing costs on job creation.

Our calibration exercise for the Netherlands suggests that when there is a large but perhaps not unrealistic underinvestment problem in specific investments, firing costs can raise productivity and employment, though a rise in productivity and employment does not guarantee a rise in welfare. When there is no underinvestment problem in specific investments, firing costs lower productivity and welfare though they may still raise employment. Still, even in the absence of specific investments (or in the absence of underinvestment in specific investments) firing taxes can improve welfare. This happens when matches are terminated too soon due to the presence of UI benefits and premiums, driving a wedge between the social and private continuation value of the match. Firing taxes can mitigate this problem without collateral damage on the creation side if the receipts are used to reduce UI premiums.

An extension of the model with endogenous labour force participation shows that the model can also produce falling employment when we increase firing costs, as suggested by our empirical findings and a number of other empirical studies.

Still, although we have made the analysis of EPL more realistic by introducing specific investments and a tenure profile for EPL, many interesting other aspects demand further study, like the insurance role of severance pay next to unemployment insurance and the role of firing procedures in *e.g.* distinguishing between shirkers and non-shirkers.

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A.1 Solving the differential equation

We want to solve the differential equation

$$\frac{\partial X(i_f, i_w, \tau, t)}{\partial t} - (r+\delta)X(i_f, i_w, \tau, t) = -(c_0 + c_f {i_f}^{\rho_f} + c_w {i_w}^{\rho_w})A(\tau) + (\widetilde{w} + p)A(t), \tag{A.1}$$

with terminal condition $S(i_f, i_w, \tau, \tau + T(\tau)) = 0$, noting that for notational convenience we introduced $X(i_f, i_w, \tau, t) \equiv S(i_f, i_w, \tau, t) + (\alpha_0 + \alpha_1(t-\tau))A(t))$. This is a non homogeneous linear differential equation of the type $\frac{dx(t)}{dt} + ax(t) = f(t)$ whose general solution is (see *e.g.* Chiang, 1984)

$$x(t) = e^{-at}\left(\int e^{as} f(s)ds + c\right), \tag{A.2}$$

where c is a constant determined by a value for x at some (relevant) date. Filling in the relevant expressions, and the relevant integration limits we obtain for some t

$$X(i_f, i_w, \tau, t) = e^{(r+\delta)t}(\int_{\tau+T(\tau)}^{t} e^{-(r+\delta)s}((\widetilde{w} + p)A(s) - (c_0 + c_f {i_f}^{\rho_f} + c_w {i_w}^{\rho_w})A(\tau))ds + c). \tag{A.3}$$

Next we fix the constant c. At $t = \tau + T(\tau)$ we have $S(i_f, i_w, \tau, \tau + T(\tau)) = 0$, so $X(i_f, i_w, \tau, \tau + T(\tau)) = -(\alpha_0 + \alpha_1 T(\tau))(f_c + f_t)A(\tau + T(\tau))$. Noting that the integral above becomes zero when the lower and upper limit are the same, we get $c = -(\alpha_0 + \alpha_1 T(\tau))(f_c + f_t)A(\tau + T(\tau))e^{-(r+\delta)(\tau+T(\tau))}$. When we fill in this value for c, switching the integration limits and to compensate for this putting a minus in front of the integral, and substituting $S(i_f, i_w, \tau, t) + (\alpha_0 + \alpha_1(t-\tau))A(t))$ back for $X(i_f, i_w, \tau, t)$ we get

$$\begin{aligned} S(i_f, i_w, \tau, t) = \int_{t}^{\tau+T(\tau)} &((c_0 + c_f {i_f}^{\rho_f} + c_w {i_w}^{\rho_w})A(\tau) \\ &-(\widetilde{w} + p)A(s))e^{-(r+\delta)(s-t)}ds \\ &+(\alpha_0 + \alpha_1(t-\tau))(f_c + f_t)A(t) \\ &-(\alpha_0 + \alpha_1 T(\tau))(f_c + f_t) \\ &A(\tau + T(\tau))e^{-(r+\delta)(\tau+T(\tau)-t)}. \end{aligned} \tag{A.4}$$

which is equation (2.10) in the main text.

A.2 First-best

We look for the optimal path of specific investments. Consider a path $i'_f(t) = i_f(t) + \phi x(t)$, where $i_f(t)$ is the optimal path. Denote the Lagrangian of the optimisation problem in 3.2.1 with the expression for $i_f(t)$ above by $V(\phi)$. When the path for $i_f(t)$ is optimal we have $\frac{\partial V(\phi)}{\partial \phi} = 0$ at $\phi = 0$. Taking the derivative with respect to ϕ and then setting $\phi = 0$ we get the following optimality condition

$$\begin{aligned}
&\int_0^\infty \int_{t-T(t)}^t c_f i_f(\tau)^{\rho_f - 1} x(\tau) A(\tau) m(\tau) e^{\delta(\tau - t)} d\tau e^{-rt} dt \\
&\qquad\qquad - \int_0^\infty x(t) A(t) m(t) e^{-rt} dt = 0. \qquad \text{(A.5)}
\end{aligned}$$

By changing the order of integration, taking into account the change in the integral limits, we can free the arbitrary expression $x(\tau)$ and derive an optimality condition per vintage

$$\int_0^\infty x(\tau) \left(\int_\tau^{\tau+T(\tau)} c_f \rho_f i_f^{\rho_f - 1} A(\tau) m(\tau) e^{\delta(\tau - t)} e^{-rt} dt - m(\tau) e^{-r\tau} \right) d\tau = 0$$

Rewriting gives for each vintage we have optimal firm specific investments

$$i_f = \left(\frac{c_f \rho_f}{r + \delta} \left(1 - e^{-(r+\delta)T} \right) \right)^{-\frac{1}{1-\rho_f}}. \qquad \text{(A.6)}$$

In a similar way we can derive the first best choice for specific investments by workers

$$i_w = \left(\frac{c_w \rho_w}{r + \delta} \left(1 - e^{-(r+\delta)T} \right) \right)^{-\frac{1}{1-\rho_w}}. \qquad \text{(A.7)}$$

Optimal job creation is somewhat harder to derive because job creation also appears in the integral constraint on unemployment. Kamien and Muller (1976) show how we can derive the first order conditions for an optimal control problem with integral state equations. Suppressing the specific investment variables we can write the following lagrangian

$$\begin{aligned}
V(m,u,\lambda) = &\int_0^\infty \int_{t-T(t)}^t A(\tau) m(\tau) e^{\delta(\tau - t)} d\tau e^{-rt} dt \\
&+ \int_0^\infty b_{ld} A(t) - c(m(t), u(t)) A(t) e^{-rt} dt \\
&+ \int_0^\infty \lambda(t) \left(1 - \int_{t-T(t)}^t m(\tau) e^{\delta(\tau - t)} d\tau - u(t) \right) dt. \qquad \text{(A.8)}
\end{aligned}$$

and then changing the order of integration

$$\begin{aligned}
V(m,u,\lambda) = &\int_0^\infty \int_\tau^{\tau+T(\tau)} A(\tau) m(\tau) e^{-\delta(t-\tau)} e^{-rt} dt d\tau \\
&+ \int_0^\infty b_{ld} A(\tau) - c(m(\tau), u(\tau)) A(\tau) e^{-r\tau} d\tau \\
&+ \int_0^\infty \lambda(\tau)(u(\tau) - 1) \\
&- \int_0^\infty \int_\tau^{\tau+T(\tau)} \lambda(\tau) m(\tau) e^{-\delta(t-\tau)} dt d\tau, \qquad \text{(A.9)}
\end{aligned}$$

define $H(m,u,\lambda)$

$$\begin{aligned} H(m,u,\lambda) = & \int_{\tau}^{\tau+T(\tau)} A(\tau)m(\tau)e^{-\delta(t-\tau)}e^{-rt}dt \\ & + b_{ld}A(\tau) - c(m(\tau),u(\tau))A(\tau)e^{-r\tau} \\ & + \int_{\tau}^{\tau+T(\tau)} \lambda(\tau)m(\tau)e^{-\delta(t-\tau)}dt \end{aligned} \tag{A.10}$$

we may then write

$$V(m,u,\lambda) = \int_0^{\infty} H(m,u,\lambda)e^{-rt}dt - \int_0^{\infty} \lambda(t)(u(t)-1)dt. \tag{A.11}$$

An optimal path for $m(t)$ has $\frac{\partial H(.)}{\partial m(t)} = 0$ and $\frac{\partial H(.)}{\partial u(t)} = \lambda(t)$. The latter gives

$$\frac{\partial H(.)}{\partial u(t)} = \lambda(t) \Rightarrow \lambda(t) = (b_{ld} - c'_u(t))A(t)e^{-rt}, \tag{A.12}$$

and the former gives

$$\begin{aligned} \frac{\partial H(.)}{\partial m(t)} = 0 \Rightarrow & \int_{\tau}^{\tau+T(\tau)} \left(A(\tau) - \lambda(t)e^{rt}\right) e^{-(r+\delta)(t-\tau)}dt = A(\tau)c'_m(\tau) \Rightarrow \\ & \int_{\tau}^{\tau+T(\tau)} (A(\tau) - (b_{ld} - c'_u(t)) \\ & A(t))e^{-(r+\delta)(t-\tau)}dt = A(\tau)c'_m(\tau), \end{aligned} \tag{A.13}$$

so job creation occurs until the marginal creation cost (the right hand side) equals the discounted stream of productivity minus the social shadow price of labour (the left hand side). The shadow price of labour is the marginal reduction in search costs of having one more unemployed plus the direct value of unemployment b_{ld}.

Optimal job destruction follows simply from differentiating (A.8) with respect to $T(t)$

$$A(t-T(t))e^{-rt} = \lambda(t) \Rightarrow A(t-T(t)) = (b_{ld} - c'_u(t))A(t), \tag{A.14}$$

matches are destroyed when the value of production in vintage $t - T(t)$ at time t equals the value of moving an individual to unemployment. The social value of an extra unemployed individual is the utility term b_{ld} and the marginal reduction in search costs from having one additional unemployed.